INVENTORY OF TIDEPOOL AND ESTUARINE FISHES IN ACADIA NATIONAL PARK

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Acadia National Park

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EXECUTIVE SUMMARY

Acadia National Park (ANP) is part of the Northeast Temperate Network (NETN) of the National Park Service's Inventory and Monitoring Program. Inventory and monitoring activities supported by the NETN are becoming increasingly important for setting and meeting long-term management goals. Detailed inventories of fishes of estuaries and intertidal areas of ANP are very limited, necessitating the collection of information within these habitats. The objectives of this project were to inventory fish species found in (1) tidepools and (2) estuaries at locations adjacent to park lands on Mount Desert Island and the Schoodic Peninsula over different seasons. The inventories were not intended to be part of a long-term monitoring effort. Rather, the objective was to sample as many diverse habitats as possible in the intertidal and estuarine zones to maximize the resultant species list. Beyond these original objectives, we evaluated the data for spatial and temporal patterns and trends as well as relationships with other biological and physical characteristics of the tidepools and estuaries.

For the tidepool survey, eighteen intertidal sections with multiple pools were inventoried. The majority of the tidepool sampling took place in 2001 but a few tidepools were revisited during the spring/summer period of 2002 and 2003. Each tidepool was visited once during late spring (Period 1: June 6 – June 26), twice during the summer (Period 2: July 3 – August 2 and Period 3: August 3 – September 18) and once during early fall (Period 4: September 29 – October 21). Physical characteristics of the tidepools were recorded along with the presence of other biological organisms like algae and invertebrates. Fish were collected, identified, counted, and measured for length. The number of tidepools containing fish did not vary much among sample periods. Twelve species of fish were identified in the tidepools. Initially, the dominant species were pollock, gunnels, and lumpfish. Pollock numbers decreased quickly and none were seen during either of the last two sampling periods. Gunnel numbers were relatively stable for the first two periods; however, their relative contribution to the catch declined during the second period due to an increased number of lumpfish caught during this period. Lumpfish were caught in 12 of the tidepools during the second sample period, suggesting a widespread occurrence. Nine tidepools contained lumpfish in the third sample period. A doubling in the number of gunnels in the third period and an increase in the number of mummichogs followed the influx of young of year (YOY) lumpfish. Gunnels were found in 13 tidepools during the third sample period. Large numbers of stickleback fry (three, four and nine-spine) and YOY mummichog were also documented to be abundant through the early summer in shallow estuarine mudflat pools and salt pannes. The mummichogs' abundance is solely attributable to one site; the only tidepool to ever contain mummichogs. Atlantic sea snails increased in numbers over the course of the season and were most abundant in the last period. The short-horned sculpin also became relatively more numerous than the other species, largely due to the declining total number of fish captured.

We examined microhabitat variables (algal and grass abundance, invertebrate abundance and physical variables) associated with the presence, absence and abundance of tidepool fishes using principal component analysis (PCA), a multivariate statistical technique. Two important trends were apparent from the principal component analyses of tidepool fish data. First, fish presence and abundance became more predictable over the course of the season. Second, in all the sample periods there was a clear trend in the groupings of fish species. There were three primary types of tidepools, those where: (1) fish were absent, (2) mummichogs and fourspine sticklebacks were present, and (3) all other fish were present. Tidepools that were lacking in algal species, were also lacking in invertebrates and fish species. The separation of mummichogs and fourspine sticklebacks from all other fish species was largely controlled by the presence of the two different tidepool habitats around ANP: rocky ledges and mudflats. The two grouping of fish were clearly separated along these lines and there appears to be little overlap.

The important physical parameters were always associated with vertical position relative to tide height, with the marine environment decreasing the temperature and increasing the salinity and the terrestrial environment increasing the temperature and decreasing salinity. For example, higher low tides resulted in reduced temperatures and increased salinities because of an greater marine influence. Whereas conditions in the high intertidal zone, being more influenced by the terrestrial environment, are likely to be more variable, with wet periods producing cooler and less saline conditions and dry periods producing warmer and more saline conditions. Salinity decreased during the year of this study.

Early in the year, the physical characteristics of the tidepools were correlated with lower trophic level algal and invertebrate communities. Later in the season, the relationships between physical variables and algae/invertebrate species became non-significant, and the fish species correlated significantly with the algae and invertebrate species present. This suggests a cascade from physical factors contributing to algal and invertebrate species presence early to algal and invertebrate species correlating to fish species later in the year. Strong relationship between invertebrate and fish species presence suggest an important role of early season biological characteristics of tidepools, and their physical conditions such as relative height of the tidepool to the sea level, in structuring the eventual fish community. The progression of ecological structuring with season suggests that initial conditions are important in laying the foundation for later structure amongst fish species. Anthropogenic alterations to the trophic-shifting of ecological structure, through oil spills and physical disturbance, will therefore have effects beyond the time period in which they occur.

Estuarine fish were inventoried during late spring and summer of 2002 and 2003, in five estuaries within Acadia National Park. Four estuaries were located on Mount Desert Island (MDI) and one was on Schoodic Point, the mainland section of ANP to the north of MDI. Physical characteristics of the estuaries were recorded along with the presence of other biological organisms like algae and invertebrates. Fish were collected, identified, counted, and measured for length. The results demonstrated that the location of culverts or sills relative to the mean tide height and local topography played an important role in structuring habitat characteristics. If the local relief is low and an impoundment of water is capable of collecting significant brackish water, the result is habitat suitable for dense populations of mummichogs and sticklebacks. Higher relief surrounding an estuary will only allow for a small pool of brackish water to form. The culverts also alter natural water column properties by forcing turbulent mixing and allow for substantial heating of the water over shallow mudflats and marshes.

The differences in culvert placement within the estuaries of Acadia National Park have important effects on the flora and fauna. We documented that the pools of brackish water created by culverts allowed for populations of mummichogs and sticklebacks to outnumber any other species. It is not clear to what extent the impoundments negatively impact desirable species such as salmon, trout, and anadromous river herring.

Management of marine species will require a comprehensive plan that includes freshwater processes. Past management, which focused on single species and systems, neglected species that move between habitats or ecosystems. A comprehensive plan will require the adoption of a broader view that incorporates different temporal and spatial scales. This may require that Park managers interact more with local, state and federal agencies charged with management of other systems.

DEDICATION

In tribute to Dr. John R. Moring, the contributors to this project would like to dedicate this work to his memory. John was a very productive writer, scientist, and teacher. He had a broad knowledge of both marine and freshwater fishes and was very interested in stream ecology, the effects of forest practices on fish habitat, and tidepool fishes. He was a dedicated teacher who, since 1979, was the major professor for 34 graduate students. He influenced many more undergraduate students throughout his tenure at the University of Maine. More importantly, he was an inspiring colleague, advisor, and friend. His friendly and gentle demeanor and quick wit are greatly missed by all those who had the honor of interacting with him, and serve as a great lesson in how to properly collaborate and advise within the academic world. Few are capable of appropriately melding personality and profession; John was one. Many people share the following sentiment regarding John: “he was one of the good guys”.

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Chapter 1

DESCRIPTION AND PURPOSE

John Moring and Linda J. Kling

A. DESCRIPTION OF PROBLEM

Acadia National Park (ANP) is part of the Northeast Temperate Network (NETN) of the National Park Service's Inventory and Monitoring Program. Inventory and monitoring activities supported by the NETN are becoming increasingly important for setting and meeting long-term management goals. Summaries of past studies of freshwater fish resources of Acadia National Park are available (Bowes et al., 1999) and more detailed inventories, with relative abundance, have been published (Moring et al., 2001). However, detailed inventories of fishes of estuaries and intertidal areas within and adjacent to Park lands are limited. Fishes inhabiting these mixing areas between the land and the ocean are extremely important components of ecosystems (Edwards et al., 1982) and can be categorized in one of three groups: intertidal, tidepool and estuarine.

Intertidal fishes are those utilizing the intertidal zone, either during flood or ebb tides. Typically they forage in the area between the low and high tide marks during the flood tide and then depart with the receding tide.

Tidepool fishes are found in isolated trapped tidepools at low tide. Tidepool fishes are also intertidal fishes, but not all intertidal fishes are tidepool fishes. Tidepool fishes include (1) those species that spend their entire life cycle, or much of it, living in tidepools and the intertidal zone, (2) juvenile stages of subtidal fishes that use tidepools as refuges from predators during the first or second year of life, and (3) occasional, rare visitors, typically intertidal species that become trapped in pools with a rapidly receding tide.

Estuarine fishes are those found in the transition zones between river mouths and the ocean, and in salt marshes. Often the species list for such areas depends on the salinity at a given location, although many estuarine fish species are euryhaline and are able to live in a variety of salinities.

Intertidal and estuarine areas are particularly susceptible to oil spills, sewage, and chemical pollutants released into coastal areas as well as to coastal development (Moring, 1983). Pollutants tend to concentrate along the shores (Boesch et al., 1974) where intertidal and estuarine species live. Even if fishes are able to physically move from an impacted area, marine algae and many forms of sessile invertebrates cannot leave. Thus, fishes can be adversely affected by the loss of habitat and important species associations in polluted areas (Boesch and Turner, 1984; Rozas and Odum, 1988; Sogard and Able 1991).

Estuaries are typically the most productive regions of coastal waters, and tidepools serve important nursery and refuge functions for many commercially important species of marine fishes in Maine waters, such as juvenile pollock (*Pollachius virens*), Atlantic herring (*Clupea harengus*), winter flounder (*Pleuronectes americanus*) and lumpfish (*Cyclopterus lumpus*). As a consequences future Park management may rely heavily on baseline inventories of species presence and their relative abundance.

Detailed inventories of fishes of estuarine areas adjacent to Park lands are very limited. Doering et al. (1995) completed an analysis of the Bass Harbor Marsh system near Bass Harbor, which included some sampling of fishes. However, the emphases of those investigations were water quality and other physical/chemical features. Fish collections were made at several stations within the estuary, periodically between the months of April and October. Some limited work on the Northeast Creek estuary targeted mummichog, *Fundulus heteroclitus*. The species present and relative abundance of fishes in other estuaries have been little investigated, if at all. Documenting fish species presence and positions relative to salinity and season in principal estuaries would provide Park managers with important baseline data.

A bit more information is available for intertidal fishes. Procter's (1933) biological examination of Mount Desert Island included intertidal and inshore marine fishes, but the collections were not quantitative. Rather, Procter only documented some species that were collected in the 1920s and 1930s. More recently, Moring (1990b) examined fish species of tidepools along Schoodic Peninsula (the mainland portion of Acadia National Park near Winter Harbor) since 1979 and provided checklists and relative abundance data for Maine tidepool fishes (Moring, 1993a). Moring also conducted more detailed investigations of individual intertidal and inshore fishes such as rock gunnel, *Pholis gunnellus* (Moring 1993b), lumpfish (Moring, 1989; Moring and Moring, 1991) and sculpins, *Myoxocephalus* spp. (Moring 2001). But intertidal fish populations adjacent to Park lands on Mount Desert Island have not been examined on a broad or even a local scale.

B. OBJECTIVES OF PROJECT

The objectives of this project were to inventory fish species found in (1) tidepools and (2) estuaries at locations adjacent to Park lands on Mount Desert Island and the Schoodic Peninsula over different seasons. The inventories were not intended to be part of a long-term monitoring effort. Rather, the objective was to sample as many diverse habitats as possible in the intertidal and estuarine zones to maximize the resultant species list. Beyond these original objectives, we have evaluated the data for spatial and temporal patterns and trends as well as relationships with other biological and physical characteristics of the tidepools and estuaries.

Chapter 2

APPROACH

John Moring, Adrian Jordaan, Pamela Bryer, Linda Kling

A. Constraints and problems encountered in field sampling

1. *Tidepools*

The coast of Acadia National Park and Schoodic Peninsula is composed of granite platforms and outcrops with occasional large boulders. Tidepools are scattered around the island and peninsula in irregular depressions in the rock, ranging in size from centimeters to tens of meters across. Tidepool fish presence in the rocky intertidal zone is seasonal in nature (Moring, 1990b; 1993a). Winter water temperatures can reach slightly below 0ºC and almost all fish species depart for subtidal waters in winter. It has been documented that fishes are generally absent from tidepools from about November through April (Moring 1990b), with the exception of the occasional presence of sculpins (*Myoxocephalus* spp.). Therefore, sampling in tidepools along the rocky shores was limited to May through October.

Intertidal sampling cannot be placed within a convenient experimental sampling design. Dates and times of sampling are, to a large extent, based on tidal cycles. The Bay of Fundy and waters adjacent to Acadia National Park have some of the highest tidal ranges in the world. Flood tides advance quite rapidly and samplers and equipment could be isolated and trapped. Some locations and their inhabitants are only accessible during certain tides, whereas estuarine sampling is more appropriately done during flood tides. In addition, many suitable tides occur at night, which limits sampling because of visibility and safety concerns. Access to the intertidal zone is often across slippery, algae-covered rocks; thus unstable footing was a major concern. During inclement weather, working in the intertidal zone can be dangerous because of water turbulence, waves, and wet rocks, and visibility of pools is impaired. As a consequence, sampling trips during poor weather was avoided.

The sampling window for tidepools exists from about 1.5 hours prior to low tide to 1.5 hours after low tide. Therefore, only one or two sampling locations could be inventoried during each appropriate low tide period. The objective was to sample each intertidal location at least once during the spring, summer, and fall. Tidepool fishes were collected using long-handled dip nets, small seines, small hand nets, small baited minnow traps, and small trawls. These techniques were shown to be efficient and productive in previous investigations (Chenoweth 1973; Morin et al., 1980; Moring 1990a). Large-scale sampling using staked gill nets in the intertidal zone was employed by Ojeda and

Dearborn (1989, 1991), however the procedures were labor-intensive, expensive, difficult to employ and dangerous to implement on a broad scale.

Within a single pool, it is not valid to create sub-sampling locations because a tidepool may contain several distinct microhabitat types. Since the purpose of this project was to maximize encounters with as many fish species as possible, the objective was accomplished by sampling a variety of habitats. Thus, we conducted a thorough search of each pool or series of pools rather than employing randomized sampling.

Given these constraints, the original project proposal predicted sampling a minimum of 12 general intertidal sections with single or multiple pools. At the conclusion of the project, 18 intertidal sections with multiple pools were inventoried (Figure 2.1). The tidepool study was broken into four sampling periods representing (1) late spring (June 6 – June 26); (2) early summer (July 3 – August 2); (3) late summer (August 3 – September 18); and (4) early fall (September 29 – October 21). The majority of the fieldwork took place in 2001 but a few tidepools were revisited during the spring/summer period of 2002 and 2003.

2. *Estuaries*

The original project proposal indicated that “a maximum of 13 estuaries will be examined for fish inhabitants, each of which borders Acadia National Park lands: Bass Harbor Marsh, Northeast Creek, Frazer Creek, Breakneck Brook/Hulls Cove, Schooner Head, Otter Cove/Otter Creek, Hunters Brook, Ship Harbor, Pretty Marsh, Stanley Brook/Seal Harbor, Whalesback/Northeast Somes Sound, and Man of War Brook/Acadia Mountain.” Many of these estuaries were very limited in size, and an inventory of fishes was not possible. At the conclusion of the project, only five estuaries were inventoried: Seal Cove, Somes Sound, Bass Harbor, Northeast Creek, and Mosquito Cove. Four of the estuaries are located on Mount Desert Island (MDI), the larger portion of Acadia National Park (ANP), and one of the estuaries is located on adjacent Schoodic Point, the mainland section of ANP on Schoodic Peninsula (see Figure 2.1).

A stratified random sampling design could have been employed, except that species distribution and abundance is largely a factor of salinity and cover. Stratifying on these variables was not feasible for this study, particularly since salinity varies unpredictably over time. Consequently, sampling was non-random and aimed to maximize fish encounters across the salinity and habitat gradients present at the time of sampling. The intent of this study was not to develop a long-term monitoring program. The sampling gear used (e.g., seines, trawls, dip nets, minnow traps) and the sampling protocols did not allow for reliable and repeatable data on abundance from year to year, although such a scheme could be developed based on the information contained within this report.

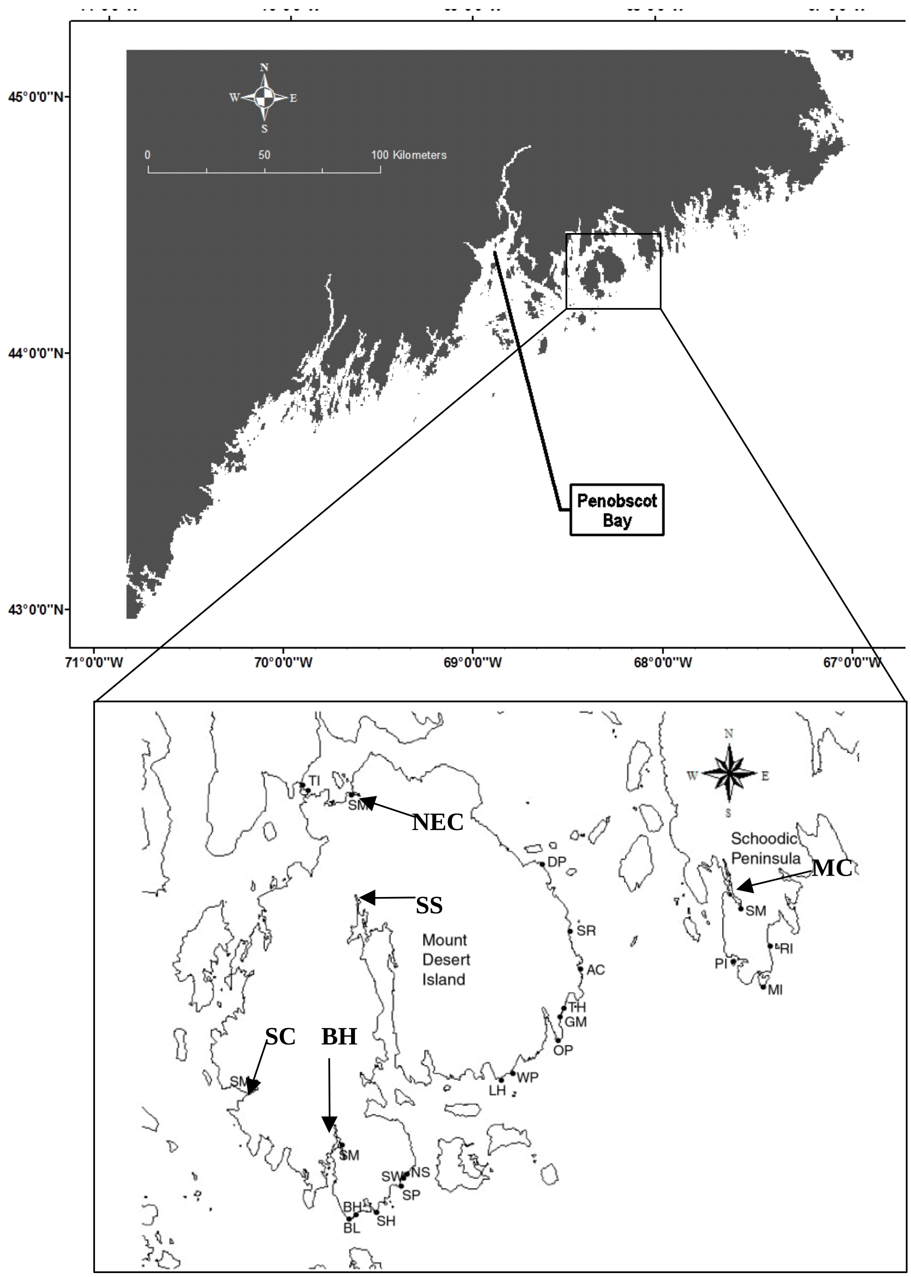

Figure 2.1. Map of sites used in tidepool and estuarine surveys. Circles demark tidepools and arrows demark estuaries. Tidepools (counter-clockwise from upper-left): TI = Thompson Island, BL = Bass Harbor Lighthouse, BH = Bass Head, SH = Ship Harbor, SP = Seawall Picnic, SW = Natural Seawall South, NS = Natural Seawall North, LH = Little Hunter's Beach, WP = Western Point, OP = Otter Point, GM = Gorham Mountain, TH = Thunder Hole, AC = Anemone Cave, SR = Schooner Rock, DP = Dorr Point, PI = Pond Island, MI = Moose Island, RI = Rolling Island. Estuaries (arrows): NEC = Northeast Creek, SS = Somes Sound, SC = Seal Cove, BH = Bass Harbor, MC = Mosquito Cove. Salt marsh panes associated with estuaries are designated with SM.

B. Sampling Procedures for Tidepool Fish Inventory

Fishes were sampled along the coast of Acadia National Park and Schoodic Peninsula (the mainland portion of Acadia National Park near Winter Harbor) from May through October 2001. There was also limited sampling of tidepools during the summer of 2002; however, the number of species captured did not increase and the results of that work will not be considered in this report.

Sampling was conducted in 39 tidepools at 18 locations that differed in habitat type, complexity, and exposure to waves. Tidepools were sampled by two people with long handled dip nets and occasionally small hand nets. Searchers stood on the side and/or in the tidepools while sampling. All moveable cover objects (i.e., rocks, surface and loose algae) were removed to expose as much of the pool as possible without permanently damaging the area. Sampling continued until all fishes encountered were captured. Each fish captured was anesthetized using MS-222 (tricaine methanesulfonate), identified, measured for total length, and returned to the tidepool where collected. Algal and invertebrate species were given a relative score ranging from 0-5. A score of 0 meant the species was absent, 1 that a couple were present, 3 that they were common, and 5 that they were extremely abundant or dominant in the pool. Scores of 2 and 4 were given if the observers determined that the species was intermediate to the other scores. Species were identified to species based on morphology, determined by consulting a number of identification materials.

Basic physical variables (depth, surface area, and bottom type) were collected for each tidepool at least once during the field sampling. Tidepools were measured across the longest axis for length (L), then measured perpendicular to this axis at the midpoint of L for the width (W). Depth was calculated by making transects along the L and W axes and averaging the measurements for each tidepool. Volume was estimated by using the volume formula for half an ellipsoid: $V = (4/3\ \pi * W/2 * L/2 * D)/2$. Tidepool area was calculated by L x W. All GPS locations were recorded in UTM meters (zone 19N) using NAD83 (North American Datum of 1983). GPS-mapping was done with a PDOP mask setting of 6, which resulted in typical positional accuracies of 3-5 m. Data on the more temporary tidepool characteristics (salinity, temperature, the presence of invertebrates, and major types of vegetation) were recorded at each sampling date.

C. Sampling Procedures for Estuarine Fish Inventory

The majority of the fieldwork took place between June 13, 2002 and August 21, 2003. Minnow traps, fyke nets, dip nets, and beach seines were used to collect fish and various invertebrates. Sampling was done in waders when the water level was low enough, and a canoe was used when the water level was too high to reach sampling sites easily. Minnow traps were used in 2002, and were supplemented with fyke nets, dip nets and beach seines. Two sampling periods were employed in 2002, one from 06-14-2002 to 07-15-2002, and the second from 08-20-2002 through 09-14-2002. The fyke net had two ends that trapped fish, one facing the ocean, the other facing the freshwater source. The inventory indicated which direction, the saltwater or freshwater side, that the fyke net was facing. For 2003, beach seines were carried out in each estuary, once a month during June, July and August; the other techniques were abandoned because of the more complete sampling achieved using seines compared to other methods.

The stations in each estuary ranged from high salinity near the estuary mouth and low salinity (~ 100% freshwater) environments near the riverine source. Physical measurements, (salinity and temperature) were recorded before each seine was conducted.

Minnow traps were placed at various locations within the estuary, attempting to gain complete coverage of all salinities. The position closest to the freshwater source was named Trap A, with the remainder placed across open water and up channels to cover the available habitats (rocky narrow channels to shallow flats) up to Trap J. If a trap was placed closer to the freshwater source than Trap A, it was labeled Trap Z. If one was moved towards the saltwater source, it was labeled Trap K, and so on. Occasionally a Trap was moved to capture a wider variety of habitats. For example, the size of Bass Harbor required that it be divided into two sampling areas: an "upper" set of sites that was close to the freshwater source, and a "lower" set of sites closer to the saltwater source. Between four and nine traps were used, with smaller numbers used in the first sample period as the Upper region was being surveyed with dip nets. Other sampling methods were used inconsistently throughout 2002 in an attempt to document species that were being missed by the traps, and to ascertain the efficiency of the traps for different species.

In 2003, the sampling shifted to seines, which gave better results, particularly for the "herring-like" species. A canoe was used to set the seine, with one end attached by a 20 m line to the shore. The seine was set in the water off the beach in an arcing manner, ending up down the bank from the other end. The net was pulled in slowly, pursing the bottom as we came closer to the shore. Fish species and invertebrates captured were documented. The stations in each estuary range from high salinity near the estuary mouth and low salinity (~ 100% freshwater) environments near the freshwater source. Physical measurements, such as salinity and temperature, were recorded before each seine was conducted. Either a SBE-19 Seabird self-contained and internally-recording CTD or YSI 85 DO, Conductivity, Salinity, Temperature Instrument from YSI Environmental was used, depending on water depth. Because the estuaries begin as wide open mud flats and constrict towards the freshwater source, two seines were used in 2003. A small seine (4.27 m X 1.2 m, 0.32 cm mesh) was used in sites that were limited in area, while a large seine (30.5 m X 1.2 m, 1.1 cm mesh) was employed when possible.

Fish species and invertebrates were documented. A subset of each species caught was measured (n = 30) and the total number of individuals was recorded. A voucher specimen of each species was collected for the Park and preserved in 95% ethanol. To avoid stressing the fish during capture and handling, MS-222 (tricaine methanesulfonate) was used to anesthetize each captured fish. Handling time was kept to a minimum and each fish was promptly returned to the water after it had been measured or counted.

D. Project Management

Dr. John R. Moring originally conceived this project. John wrote the project proposal and managed the project activities through April 2002. He hired and trained the field staff involved in the tidepool inventory of 2001. Pamela Bryer was the primary field assistant during that time with help from several graduate students (Adrian Jordaan, Susan Hayhurst, and Regina Purtell) and Natasha Hussey, a high school student at the time. Towards the end of the 2001 field season, Adrian Jordaan was selected by Dr. Moring to continue with the tidepool and estuary inventories as the primary field assistant. He had numerous conversations with Dr. Moring on the methodology to employ in the inventories. On May 9, 2002, Dr. Moring died unexpectedly, leaving the project unfinished and without a Principal Investigator. Dr. William Krohn, Leader of the Maine Cooperative Fish and Wildlife Research Unit, asked Dr. Linda Kling if she would assume the role of Principal Investigator of the project. She assumed that position on June 10, 2002. She continued with the same strategies outlined previously by Dr. Moring. Mr. Jordaan continued as the primary field assistant during 2002. While conducting the field studies, Mr. Jordaan's interest in the project intensified. He began a Ph.D. program under the supervision of Dr. Yong Chen in 2002 and elected to continue the investigation of intertidal and estuary fishes using the data collected during the previous years. He also continued with a more extensive inventory of ANP estuary fish in 2003. While Dr. Kling continued administrative responsibilities for the project, Mr. Jordaan, with guidance from Dr. Chen, assumed more and more of the technical responsibilities.

Chapter 3

INVENTORY OF TIDEPOOL FISHES IN ACADIA NATIONAL PARK

Pamela Bryer, Adrian Jordaan, Regina Purtell, Susan Hayhurst and Linda Kling

This chapter describes the tidepools surveyed and enumerates the fish species captured. General physical characteristics and locations of the tidepools surveyed in the study are given in Table 3.1. A list of fish species by common and scientific name caught during the tidepool survey on Mount Desert Island and Schoodic Peninsula is presented in Table 3.2. Numbers of individuals caught during the study pooling all tidepools within location and sampling periods is presented in Table 3.3. For more quantitative descriptions of individual tidepools, refer to Appendix II for fish enumeration, Appendix III for relative abundances of algae, and Appendix IV for relative abundances of invertebrates.

Tidepools were as likely to be rectangular as elliptical. Tidepool dimensions were estimated by measuring across the longest axis for length (L), and perpendicular to this axis at the midpoint of L for the width (W). Average depth was calculated by making transects along the L and W axis and averaging the measurements for each tidepool. Volume was estimated by using the volume formula for half an ellipsoid: $V = (4/3 \pi * W/2 * L/2 * D)/2$. Tidepool area was calculated by L x W. The average tidepool area was 17.7 m^2 with the minimum being 0.7 and the maximum being 116.5. The average depth of all the tidepools was 0.32 m with the shallowest being 0.03 and the deepest being 3.21.

A. Anemone Cave

The Anemone Cave site consisted of eight tidepools. The individual tidepool dimensions are documented in Table 3.1. A cave at the location had been popular tourist attraction for decades before the eventual destruction of the anemones that had given the site its name (Bruce Connery, Personal Communication). Although the area is no longer as conspicuous to tourists as it was historically, there is still substantial visitor use of the area. The tidepools were all generally shallow, and for that reason are probably more susceptible to visitor impacts. AC01 was located within Anemone Cave and was largely bare with some small anemones, and was twice the depth of the other tidepools at this location. The remaining pools were all located outside the cave, and were shallow at between 15% and 44% of the average tidepool depth. AC01 and AC04 were the largest in area and both approximately 10% greater than the average tidepool area. AC02, AC03, AC05, and AC07 were all small pools with areas between 10% and 15% the average tidepool area. AC02 was densely filled with algal growth. AC03 had some algal growth.

AC04 had cobbles and some algae offering available cover. AC05 was often inundated with water due to its low position relative to mean tide level, and for that reason was not sampled during all four of the sample periods. AC06 was located at a highest position relative to the mean tide level and contained primarily bare rock substrate. Algal cover dominated AC07. AC08 was a shallow pool with some overhanging rockweed and some low growing benthic algae. The only fish caught at the Anemone Cave site was a single short-horned sculpin (Table 3.3).

B. Bass Head

This site was originally inventoried as five tidepools, but eventually tidepools 3, 4, and 5 were demonstrated to be one continuous tidepool with shallow ledges that separated the pool into 3 sections. The individual tidepool dimensions are documented in Table 3.1. BH01 was closest to the ocean of the three, and only 20% - 25% of the average tidepool depth and area. BH02 was an elongated narrow crevasse that ran between two large exposed granite rocks, which resulted in it only being 11% of the average tidepool area, and was the only pool at this location that was near the average tidepool depth. For BH02 the depth was always more than half the width of the pool, whereas the other tidepools were much more open and shallow. BH03 was approximately half the average depth of all tidepools. All three tidepools had a mixed macroalgae community. At total of 40 fish were captured at Bass Head (Table 3.3). Rock gunnels were captured during every visit to this group of tidepools, while lumpfish and snailfish were caught in the first two and last two sampling trips, respectively. A short-horned sculpin was also captured during the last sampling period (Table 3.3).

C. Bass Head Lighthouse

This site consisted of two tidepools. The individual tidepool dimensions are documented in Table 3.1. The upper pool, BL01, was shallow, elongate, and covered partially by overhanging rocks. The lower pool, BL02, was round, deep and contained many large rocks. The pools were 7% and 14%, respectively, of the average tidepool area of pools sampled, but BL01 was much shallower at 28% of average, and BL02 was the deepest tidepool sampled at 3.2 m, deeper by a factor of ten than the average of all tidepools sampled. No fish were ever captured in BL01, but 38 fish were caught at BL02 with rock gunnels being abundant. One Atlantic sea snail was also captured (Table 3.3).

D. Dorr Point

The Dorr point site contained only one large tidepool (DP01). DP01 was both larger, at 30 m^2 (173% larger than average) and deeper, at 0.4 m (125% the average depth), than the average of all tidepools. The pool had a sloping depth profile with gravel, rocks, and cobble as the primary substrate. The deeper part of the pool had algal growth; in particular laminaria fronds that allowed significant cover around the margin of the pool. The interior of the pool remained open and without vegetation. A total of 115 fish were captured at Dorr Point tidepools. Pollock were often trapped by retreating tides and used the laminaria as cover during sampling. The laminaria was also where the rock gunnels and lumpfish were caught, while sculpins were caught on the substrate. A sea raven and six Atlantic snailfish were also captured at this tidepool (Table 3.3).

E. Gorham Mountain

The Gorham Mountain site had two tidepools. GM01 was a large circular pool with substantial algal growth. GM02 was approximately equal in area to GM01, and both were near 14 m^2, 20% smaller than the average area. GM02 was substantially shallower at 0.19 m deep, compared to GM01, which was 0.97 m deep. . The catches of both pools were variable and ranged from 0 to 6 individuals. At total of 27 fish were caught at this site representing five species of fish: short-horned sculpin, grubby, rock gunnel, lumpfish and Atlantic snailfish (Table 3.3).

F. Little Hunters Beach

Little Hunters Beach contained only two tidepools. The individual tidepool dimensions are documented in Table 3.1. LH01 was half the average area (8.8 m^2), 72% of the average depth at 0.23 m and was located relatively close to the mean tide level. The pool contained substantial macroalgal growth. LH02 was a shallow pool located at the base of a rock ledge and relatively high in the intertidal zone compared to LH01. LH02 had an area larger than the average by approximately 24% at 21 m^2, but a depth (0.17 m) about half the average tidepool depth. Only 17 fish were captured. Rock gunnels were the most commonly captured fish at LH02; short-horned sculpin were occasionally captured. Longhorn sculpin were abundant at LH01 along with an occasional Atlantic snailfish (Table 3.3).

G. Moose Island

The Moose Island site on the Schoodic peninsula contained two tidepools. The individual tidepool dimensions are documented in Table 3.1. MI01 was a shallow, approximately 67% shallower than the average depth, and small, approximately 41% of the average area, located on a rocky outcrop. The pool was densely filled with macroalgae and located relatively low compared to mean tide height. The combination of low position, on a rocky outcrop, and an exposed coastline meant that the tidepool was often susceptible to high wave action. MI02 was a long crevasse that had higher than average area and depth. Fringing algae, in which a mating pair of threespine sticklebacks was found, encircled the pool. A couple of large boulders added to the cover available in the tidepool. A couple of short-horned sculpins were also captured. A total of only six fish were captured (Table 3.3).

H. Natural Seawall - North

This site contained two tidepools in a northern location along the natural seawall. The individual tidepool dimensions are documented in Table 3.1. Both NN01 and NN02 were shallow pools located along an extensive rockweed bed. NN01 was 2.2 times larger than the average tidepool area but only 19% of the average tidepool depth. NN02 was below average in both area and depth at 70% and 69% of the average values, respectively. Only two fish were captured, both Rock gunnels (Table 3.3).

I. Natural Seawall - South

This site had two tidepools that were south of NN01 and NN02. The individual tidepool dimensions are documented in Table 3.1. NS01 was a large tidepool, at 58% greater than the average tidepool area, with mixed algal species overhanging from rocky margins and growing from substrate. NS02 was closer to the mean tide level than NSO1 and was more of an elongate shape which reduced the area to 15% the average tidepool area, with algae overhanging from rocky margins and many periwinkle shells collecting in the center of the pool. The depth of both pools was near 30% below the average tidepool depth.

A total of 101 fish were caught at this site and six species were represented: pollack, short-horned sculpin, grubby, rock gunnels, lumpfish and Atlantic snailfish (Table 3.3). Of particular interest was (1) the recapture of a very large short-horned sculpin in the last two samples, with measurements of 16.5 and 17.1 cm respectively, and (2) the large number of Atlantic snailfish living within the periwinkle-dominated substrate that were captured in NS02 during the third sample period.

J. Otter Point

There were three tidepools at the Otter point site. The individual tidepool dimensions are documented in Table 3.1. Two open pools with areas 5.8 (OP01) and 2.7 (OP03) times larger than the average, and depths near average for OP01 and 60% greater than average for OP03. OP03 was high relative to mean tide level compared to OP01 and OP02. OP02 was a small depression only 6% of the average area and 56% of the average depth with large cobble substrate directly overlying bedrock. A total of 49 fish were captured. Rock gunnels were the most frequently caught species, but short-horned sculpin and Atlantic snailfish were most abundant. A couple grubby and Lumpfish were also captured (Table 3.3).

K. Pond Island

There was one tidepool at the Pond Island location on Schoodic Point. The individual tidepool dimension is documented in Table 3.1. PI01 was below average in area and depth at 64% and 56% of the average values, respectively. Large stones, rocks, gravel and mud with mixed algal growth, dominated the substrate. A total of 32 fish were captured at this location with a diverse fish community comprising seven species of fish (Table 3.3). Rock gunnels, short-horned sculpin and lumpfish were all captured on every sampling date, except the last in late October. In addition, five grubby, a couple of Atlantic snailfish, a sea raven and a winter flounder were captured. This was the only tidepool where a winter flounder was captured.

L. Rolling Island

The Rolling Island location also only had one tidepool. The individual tidepool dimension is documented in Table 3.1. This tidepool had an area (73 m^2) four times larger and 81% greater depth than average values. The pool had a substrate ranging from gravel to multiple boulders with moderate numbers of mixed algal species. A total of 46 fish were captured with five species represented (Table 3.3). Pollock were captured at this pool on two occasions and lumpfish, short-horned sculpin, rock gunnels and snailfish were common.

M. Ship Harbor

Three tidepools were sampled at the Ship Harbor location. The individual tidepool dimensions are documented in Table 3.1. SH01 was only 17% of the average tidepool area but was 68% deeper than the average depth. The substrate of SH01 was composed of solid bedrock and large stones, with a mixed algal community of moderate abundance. SH02 was 35% the average area and slightly above average depth, with gravel, cobble, large stones, and bedrock dominating the substrate. A mix of algal species with moderately high abundance covered much of the substrate. SH03 was the largest of the three tidepools sampled at Ship Harbor at only 68% of the average area, but was the shallowest at 59% of the average tidepool depth. The substrate was largely bedrock, with an occasional boulder, on which a diverse macroalgal community grew. A total of 26 fish were captured here representing four species of fish (Table 3.3). Rock gunnels and lumpfish were common earlier in the season, while snailfish numbers increased in the last two sampling periods. A couple of short-horned sculpins were also captured.

N. Seawall Picnic

Only one tidepool was sampled at the Seawall Picnic site. The individual tidepool dimension is documented in Table 3.1. SP01 was the largest tidepool inventoried, at 116

m^2, 6.8 times the average tidepool area in this study. The depth was larger than the average depth by 56%. The pool had multiple cracks and crevasses along a convoluted edge. A moderately high abundance of mixed algal species covered much of the substrate of gravel, boulders, and bedrock. A total of 73 fish were captured with four species of fish represented (Table 3.3). Lumpfish and snailfish were consistently captured here, while short-horned sculpin and rock gunnels were present in the second sampling trip.

O. Schooner Head Road

The Schooner Head Road site had two tidepools. The individual tidepool dimensions are documented in Table 3.1. Both SR01 and SR02 were smaller than the average tidepool area by 49% and 74%, respectively. SR02 had a depth of 0.03 m, slightly more than twice the depth of SR01. SR01 and SR02 had a solid bedrock substrate with many nooks and cracks, all covered by a mixed algal community dominated by rockweed and laminaria. A total of 15 fish were captured representing four species of fish; lumpfish, short-horned sculpin, rock gunnel and snailfish were caught over the four sample periods (Table 3.3).

P. Thunder Hole

There were two tidepools at the Thunder Hole site. The individual tidepool dimensions are documented in Table 3.1. TH01 and TH02 were 63% and 34% of the average area. TH01 was double, and TH02 22% less than the average depth. TH01 was dominated by a laminaria species in high abundance over a solid bedrock substrate, covering most of the surface and bottom of the pool. TH02 contained a mixed algal community with a slightly dominant rockweed community over a bedrock and gravel substrate. A total of 12 fish were captured representing three species of fish: Atlantic snailfish, lumpfish and short-horned sculpins.

Q. Thompson Island

There were two tidepools at the Thompson Island location on the north side of Mount Desert Island. The individual tidepool dimensions are documented in Table 3.1. TI01 and TI02 were 5% below and 34% above the average area (17 m^2), respectively. Both were shallow at 12% and 9% of the average tidepool depth (0.32 m), due to the mudflat habitat in which they were located. The mudflat had occasional boulders embedded within the mud from which rockweed grew giving some cover within the pools. Dead rockweed fronds were also common in the pools. Over 4,000 fish were captured at Thompson Island tidepools representing three species of fish (Table 3.3). Mummichogs and threespine and fourspine sticklebacks were dominant members of the fish community at this site. A large number of unidentified stickleback fry were captured and only approximate numbers were recorded.

R. Western Point

There were two tidepools sampled at Western Point. The individual tidepool dimensions are documented in Table 3.1. WP01 was 25% larger in area, and 6% shallower, than the average values. The substrate was bedrock with a mixed algal community covering it. WP02 was 52% and 59% of the average tidepool area and depth, respectively. It contained a complex mixture of nooks and cracks over a rocky substrate. A total of 18 fish were captured representing three species of fish (Table 3.3). Short-horned sculpin were caught in every sample period, while rock gunnels were caught in three of the four sample periods. Three lumpfish were captured in one sampling.

Table 3.1. Tidepool location and dimensions. The length (L), width (W), area (A), average depth (D) and volume (V) of each tidepool sampled. The relative area (RA), depth (RD) and volume (RV) are presented as a percentage of the average.

Site	Pool ID	Northing	Easting	L (m)	W (m)	A (m2)	D (m)	V (m3)	RA (%)	RD (%)	RV (%)
Anemone Cave	AC01	4910063	565596	5.0	4.0	19.0	0.0	2.9	111	90	93
	AC02	4910064	565638	2.0	1.0	3.0	0.0	0.2	15	41	6
	AC03	4910064	565638	3.0	1.0	2.0	0.0	0.1	11	44	5
	AC04	4910063	565560	13.0	1.0	19.0	0.0	0.5	110	16	16
	AC05			2.0	1.0	2.0	0.0	0.1	12	37	4
	AC06	4910042	565643	3.0	2.0	6.0	0.0	0.4	33	41	12
	AC07	4910196	565573	2.0	1.0	2.0	0.0	0.1	12	37	4
	AC08	4910205	565546	10.0	1.0	9.0	0.0	0.4	49	28	13
Bass Head	BH01	4896737	553202	3.0	1.0	3.0	0.0	0.1	20	25	5
	BH02	4896739	553203	3.0	1.0	2.0	0.0	0.3	11	106	11
	BH03	4896744	553225	4.0	1.0	5.0	0.0	0.5	29	56	15
	BH04			1.0	1.0	1.0	0.0	0.1	4	59	2
	BH05			2.0	1.0	3.0	0.0	0.4	20	69	12
Bass Head Lighthouse	BL01	4896719	553011	2.0	1.0	1.0	0.0	0.1	7	28	2
	BL02	4896714	553015	2.0	1.0	2.0	3.0	4.0	14	1001	128
Dorr Point	DP01	4913828	564446	9.0	3.0	30.0	0.0	6.3	173	125	201
Gorham Mountain	GM01	4907393	564568	6.0	3.0	14.0	1.0	7.1	81	303	227
	GM02	4907402	564562	7.0	2.0	14.0	0.0	1.4	80	59	44
Little Hunters Beach	LH01	4905217	562954	4.0	2.0	9.0	0.0	1.1	50	72	34
	LH02	4905236	562961	9.0	2.0	21.0	0.0	1.9	121	53	59
Moose Island	MI01	4909033	575846	4.0	3.0	11.0	0.0	0.8	65	41	25
	MI02	4909056	575775	11.0	2.0	24.0	0.0	4.5	137	112	142
Natural Seawall - N	NN01	4898990	555987	7.0	6.0	38.0	0.0	1.2	219	19	38
	NN02	4898977	555987	9.0	1.0	12.0	0.0	1.4	69	69	44
Natural Seawall - S	NS01	4898899	555955	2.0	1.0	2.0	0.0	0.3	13	75	9
	NS02	4898877	555967	10.0	3.0	27.0	0.0	3.1	155	69	98
Otter Point	OP01	4906250	564419	12.0	8.0	99.0	0.0	16.4	569	99	519
	OP02	4906248	564410	1.0	1.0	1.0	0.0	0.1	5	56	3
	OP03	4906264	564327	12.0	4.0	46.0	1.0	12.2	262	159	387
Pond Island	PI01	4910620	574369	4.0	2.0	11.0	0.0	1.0	63	56	33
Rolling Island	RI01	4911136	576092	19.0	4.0	73.0	1.0	22.2	422	181	707
Ship Harbor	SH01	4897092	554487	2.0	1.0	3.0	1.0	0.8	17	168	26
	SH02	4897090	554528	3.0	2.0	6.0	0.0	1.1	34	106	34
	SH03	4897123	554532	4.0	2.0	11.0	0.0	1.1	63	59	35
Seawall Picnic	SP01	4898322	555885	17.0	7.0	117.0	1.0	30.5	671	156	969
Schooner Head Rd	SR01	4912237	565156	5.0	2.0	9.0	0.0	0.6	50	41	19
	SR02	4912242	565163	5.0	1.0	4.0	0.0	0.7	26	94	22
Thunder Hole	TH01	4907791	564766	4.0	3.0	11.0	1.0	3.7	63	200	116
	TH01	4907745	564706	4.0	1.0	6.0	0.0	0.8	34	78	24
Thompson Island	TI01	4919557	550666	5.0	3.0	16.0	0.0	0.3	93	12	11
	TI02	4919705	550459	7.0	3.0	23.0	0.0	0.4	131	9	11
Western Point	WP01	4905696	563721	6.0	4.0	22.0	0.0	3.4	125	94	108
	WP02	4905696	563721	5.0	2.0	9.0	0.0	0.9	52	59	29

Table 3.2. List of species by common and scientific name with their abbreviations

Common Name	Scientific Name	Abbreviation
Pollock	*Pollachius virens*	*POVI*
Mummichog	*Fundulus heteroclitus*	*FUHE*
Threespine stickleback	*Gasterosteus aculeatus*	*GAAC*
Fourspine stickleback	*Apeltes quadracus*	*APQU*
Longhorn sculpin	*Myoxocephalus octodesemspinosus*	*MYOC*
Shorthorn sculpin	*Myoxocephalus scorpius*	*MYSC*
Grubby	*Myoxocephalus aenaeus*	*MYAE*
Sea raven	*Hemitripterus americanus*	*HEAM*
Rock gunnel	*Pholis gunnellus*	*PHGU*
Lumpfish	*Cyclopterus lumpus*	*CYLU*
Atlantic seasnail	*Liparis atlanticus*	*LIAT*
Winter flounder	*Pseudopleuronectes americanus*	*PSAM*

Table 3.3. Numbers of individuals caught during 2001, pooling all tidepools within location and sampling periods. Numbers in italic are estimates. See Table 3.2 for description of abbreviations. The complete inventory is found in Appendix 2.

	POVI	**FUHE**	**GAAC**	**APQU**	**MYOC**	**MYSC**	**MYAE**	**HEAM**	**PHGU**	**CYLU**	**LIAT**	**PLAM**	**FRY**	**Tidepool**
Anemone Cave						1								1
Bass Head						2			23	7	8			40
Bass Head Lighthouse									37		1			38
Dorr Point	33				2	4	3	1	15	51	6			115
Gorham Mountain						13	3		3	3	5			27
Little Hunters Beach					9	1			5		2			17
Moose Island			4			2								6
Natural Seawall - North									2					2
Natural Seawall - South	12					12	3		15	39	20			101
Otter Point						18	2		11	3	15			49
Pond Island						11	5	1	4	8	2	1		32
Rolling Island	7					8			4	14	13			46
Ship Harbor						2			9	9	6			26
Seawall Picnic						4			3	59	7			73
Schooner Head Road						3			2	8	2			15
Thompson Island		598	*122*	*420*									*3250*	*4390*
Thunder Hole						3				1	8			12
Western Point						8			7	3				18
Species Total	52	*598*	*126*	*420*	11	92	16	2	140	205	95	1	*3250*	*5008*

Chapter 4

TIDEPOOL FISH IN ACADIA NATIONAL PARK: PATTERNS AND TRENDS

Adrian Jordaan

A. Introduction

Tidepools in and adjacent to Acadia National Park are on a part of the Maine coast with substantial public use and a high expectation that natural habitats will be conserved. In order to make sound decisions regarding management within the intertidal environment along the coastal zone, it is important to determine what species inhabit the intertidal environment, how these species interact with one another and with the available habitat, and, eventually, what the likely consequences of coastal changes will be for these species and their habitat relationships. This inventory is the first step in understanding the influence of human activities on intertidal ecosystems.

Based on observations of tidepool fish from many habitats and coasts, Zander et al. (1999) made predictions regarding the general characteristics of fish species expected in tidepools. These predictions were derived from the need for adaptation in body plan and physiology to enable survival in a stressful environment (Zander et al. 1999). Important stressors of the tidepool environment are (1) temperature fluctuation, (2) salinity fluctuation, (3) desiccation, (4) low oxygen, and (5) wave activity (Horn et al. 1999). The dynamic nature of the tidepool habitat offers the potential for adapted species to exploit unused food sources and find refuge from predators, but these species must balance the benefits of food availability against the physiological costs and the potential for predation from both aquatic and terrestrial (including avian) sources.

There are two classes of tidepool species: those that live in tidepools on a more permanent basis (resident species), and those that move in and out in a more ephemeral way (transient species). Since there are periods of time during the Maine winter that there are essentially no fish in tidepools (Moring 1990b), it could be said that there are no truly resident tidepool species. However, we will consider resident and transient species within the context of the tidal cycle. Resident species will be those that occupy tidepools consistently over repeated sampling events, while transients will be viewed as regular visitors to the intertidal zone that move from location to location and may be simply trapped in tidepools by ebbing tides. Determination of resident species is based on the observations of this study and those from Moring (1989, 1990b, 1993a,b, 2001a,b) and Moring and Moring (1991).

There are some expectations for the general body plan and ecology of these two classes of species (Zander et al. 1999). Resident species are expected to have some combination of (1) reduced or absent swimbladder, (2) small size (less than 30 cm) and/or dorso-ventrally flattened, (3) dermal calcifications (for increased density and robustness), (4) a clinging organ, and (5) an ability to tolerate low oxygen. Transient species are expected to have (1) a functional swimbladder, (2) a more classic laterally compressed fish body morphology, and (3) effective fins.

The list of species caught in the tidepool survey and their general taxonomic information is given in Table 4.1 along with their general taxonomic classification. The body plan and characteristics of those species are given in Table 4.2. From the results it appears that the resident species did have some measure of adaptation to persist in tidepool conditions.

B. Description of fish species found

Most transient tidepool species are pelagic and most resident tidepool species are benthic (Zander et al. 1999). The sole true pelagic species captured in tidepools was the pollock. Pollock enter into coastal areas during the summer and have been found in tidepools and within the intertidal zone in the Gulf of Maine (Du Buit 1991, Rangley and Kramer 1995a,b). Diet studies from the North Atlantic demonstrate the pelagic nature of its food. During their first two years, pollock inhabit coastal waters and feed on planktonic invertebrates. Following the inshore life stage, pollock migrate to the open ocean and larger euphausiids, fish, and cephalopod prey become the mainstay of their diet (Du Buit 1991). The pattern of intertidal use described by Rangeley and Kramer (1995a,b) suggested that aggregations of pollock move from subtidal habitats during low tide to occupy rocky intertidal habitat during the flood tide. They were observed to disperse into smaller groups or solitary individuals across the intertidal habitat. Algae-rich habitats had more pollock than open habitats, likely in response to avian predation risk, and the population declined an order of magnitude over the summer as the distribution of individuals shifted to deeper habitats. Our observations are consistent with Rangeley and Kramer, and we observed large schools of pollock aggregating as the tides receded. We believe that although pollock can survive in tidepools, their ecology and tendency to only be caught in large tidepools during the ebb tide make it a true transient species. Also, their presence was restricted to early in the year, probably due to a combination of lower temperature and higher oxygen conditions (Collette and Klein-MacPhee 2002).

Another transient species was the winter flounder, which was only caught once in a tidepool. Although this species is known to inhabit the intertidal zone, in particular as a juvenile (Collette and Klein-MacPhee 2002), it was not a resident species in this study and only appeared in tidepools when caught by ebbing tides. In addition, the sea raven was only caught once and was therefore also considered a transient species.

The two stickleback species were designated as transient species, although this needs to be clarified. Both threespine and fourspine sticklebacks display courtship involving a male-built nest and guarded nest territory (Collette and Klein-MacPhee 2002). Fourspine sticklebacks are usually confined to brackish water and do not have a great ability for dispersal due to small fins (Collette and Klein-MacPhee 2002). The abundance of fourspine sticklebacks at the Thompson Island sites suggests an origin from Northeast Creek and other freshwater sources on the landward side of the island, either through freshwater discharge or due to density dependent habitat choice (Worgan and FitzGerald 1981). The species was abundant in terms of numbers, but was restricted to the mud flat site, where young fish were trapped in the shallow tidepools exposed at the low tide. These observations contrast with those of the threespine stickleback, which appears to utilize open ocean habitats during most of the year and moves into the intertidal habitat to spawn and die in their second or third year (Collette and Klein-MacPhee 2002). Young threespine sticklebacks were also found in the shallow mudflat tidepools with the fourspine sticklebacks. Threespine sticklebacks were also captured as a mating pair in thick submerged vegetation at a Moose Island tidepool on the Schoodic peninsula. The results suggest that both species of sticklebacks found in tidepools were generally trapped in mudflat tidepools during ebbing tides, except that threespine sticklebacks may occasionally use tidepools for nest sites.

Horn and Ojeda (1999) predicted the presence of herbivorous fish in the upper reaches of the intertidal zone in regions between 49°N and 49°S latitudes. However, we did not find herbivorous fishes in the Gulf of Maine intertidal habitat. This suggests that, as in the case of temperate streams, fish production is based on available invertebrate production, particularly from plant shredders and terrestrial drift. It has been noted that fish entering the intertidal zone are more full on departure than on arrival (Zander et al. 1999). Fish may be an important vector for the movement of energy from the intertidal zone into the oceanic ecosystem.

The sole and partial exception to herbivory is the omnivorous mummichog, which has been found to eat eelgrass and diatoms as well as amphipods, fish eggs and small fish (Collette and Klein-MacPhee, 2002). The mummichog displays an exceptional ability to tolerate a large number of stressors. Mummichogs are particularly abundant in salt marsh, mud flat, and estuarine habitats, as well as impacted sites (Collette and Klein-MacPhee 2002). This species is capable of breathing air in oxygen-poor environments (Collette and Klein-MacPhee 2002), which along with their eurythermal and euryhaline nature and diet breadth allow them to inhabit environments that would be considered sub-optimal to other species. This includes areas facing eutrophication and solar heating that decrease the oxygen concentrations to levels inadequate for most other species. This species also exhibits a degree of homing ability, although it appears that this behavior has only been observed in tidal marsh habitats (Gibson 1999). As is the case with the fourspine stickleback, the mummichog was found in high numbers in very shallow mud pools on the landward side of MDI.

The sculpin species were generally considered resident species, except for the related sea raven, which was only caught once in a tidepool. Sea raven generally inhabit depths greater than 2 m (prefer 37–108 m) and cooler water temperatures (Collette and Klein-MacPhee 2002), and our results support these characterizations. The remaining sculpins, the longhorn, short-horned and grubby, were found to regularly inhabit tidepools. All three species are commonly found along the shoreline in southern New England (Collette and Klein-MacPhee 2002). The grubby is considered a warmer water species and the short-horned a cold-water species with antifreeze protein capability. The short-horned sculpin is the species that has been found to have some tidepool occurrence in the winter (Moring 1990), and this is likely due to the presence of antifreeze protein. Collette and Klein-MacPhee (2002) noted that the short-horned sculpin is the only species that remains close to the shore during the coldest periods of the year. Our data supports this observation because we noted an increased proportion of short-horned sculpin in the catch during the last sample period. The longhorn sculpin is the most common sculpin along the coast of Maine, but it occupies a wider depth range (Collette and Klein-MacPhee 2002), explaining the lower numbers in sampled tidepools.

The sculpins also have a remarkable ability to alter their color patterns to match the background substrate (Collette and Klein-MacPhee 2002), a characteristic that allows this species to evade predators and feed on unsuspecting prey as a sit-and-wait predator. We believe that the sculpins, and gunnels, benefit from the large numbers of young fish that seasonally enter the tidepools, in particular the lumpfish that appear to decrease in numbers quickly from the time they are initially observed. The lumpfish are not listed as a prey of any sculpin, but the short-horned and longhorn are both known to eat young fish (Collette and Klein-MacPhee 2002). It is noted that all sculpin species are voracious feeders on a large number of invertebrates, and for that reason are likely an extremely important factor in tidepool ecology.

The rock gunnel is found in temperate tidepools across the Atlantic basin and into the North Sea (Zander et al. 1999). In a tagging experiment it was found that 13% of tagged gunnels were recaptured under the same rock where they were initially captured (Zander et al. 1999). A widespread resident of tidepools across the Atlantic, the gunnel uses its anguiliform body form to advantage by hiding in algal fronds or in crevasses and under rocks. This fish avoids desiccation through behavioral modifications rather than physiological adjustments. The rock gunnel appears to have the ability to remain out of water in moist areas, such as under algae (Collette and Klein-MacPhee 2002). Although we never documented a fish in a supratidal habitat (above water level), the best candidate is the rock gunnel. It is plausible that rock gunnels may move across terrestrial surfaces at night.

Lumpfish and snailfish are both equipped with an adhesive organ that allows them to grasp algae, rocks, and other surfaces within tidepools. There were some significant differences in the behavior and ecology of the two species. First, snailfish arrived in the tidepools in the late summer and fall, when the lumpfish were beginning to leave. Lumpfish may home to specific tidepools (Moring and Moring 1991). They were not collected in tidepools until the observed temperature reached 12.7°C and began to leave as the temperature dropped below 9.3°C, as the algal cover began to die (Moring 1990). Lumpfish have been found to associate with floating masses of rockweed (Blacker 1983). In this study, lumpfish were strongly associated with algae and were often initially confused with broken *Ascophyllum* floats and other algal fragments. Furthermore, on one sampling day within the Mosquito Cove estuary, large rockweed mats were found floating and stranded along the shore with the receding tide. The floating algae were inundated with large numbers of lumpfish, many of which also became stranded along the shore. This suggests that floating rockweed mats may aid lumpfish dispersal, providing they remain offshore or in rocky intertidal areas. Lumpfish feed on a wide variety of species, and are one of only a few fish that have been shown to feed heavily on ctenophores and other jellyfish. Juvenile lumpfish feed on crustaceans that are abundant in the nearshore waters (Collette and Klein-MacPhee 2002).

Snailfish were rarely found on vegetation and were often captured under rocks, in crevasses and among periwinkles and their shells, which were occasionally abundant, on tidepool bottoms. They are rarely found in temperatures above 12°C (Detwyler 1963), which may explain their presence later in the year than the lumpfish.

Interestingly, both adhesive species have male parental care of nest sites after courtship. Many intertidal fish do not spawn pelagic eggs; instead courtship occurs within nest sites and there is often some form of parental care (DeMartini 1999). These were characteristics of a number of species: the threespine and fourspine sticklebacks, lumpfish and snailfish. Rock gunnels have also been shown to have biparental care, with one parent coiling around the egg mass (Coleman 1999). The sculpins all have benthic egg masses without parental care (Collette and Klein-MacPhee, 2002). Mummichogs lay eggs high in the tidal marsh that are often exposed to air without any adverse effects.

C. Trends relative to season

The study was broken into four sampling periods representing (1) late spring (June 6 – June 26); (2) early summer (July 3 – August 2); (3) late summer (August 3 – September 18); and (4) early fall (September 29 – October 21). The number of tidepools containing fish did not vary much among sample periods. We found that 49% (N = 39), 53% (N = 38), 39% (N = 36), and 43% (N = 37) of the tidepools contained fish in each of the four sampling periods, respectively. Initially, the dominant species were pollock, gunnels, and lumpfish in terms of the numbers of pools occupied or frequency within observed pools

(Figure 4.1). Pollock numbers decreased quickly and none were seen during either of the last two sample periods. Gunnel numbers were relatively stable for the first two sample periods, even though their relative contribution to the catch declined in the second sample period. The decrease in their relative contribution to the catch resulted from the increased number of lumpfish.

The average length of the fish and the total number of fish show an inverse relationship as young-of-year (YOY) fish enter pools, increase in size and their numbers reduce through habitat use and selective mortality. The average length dropped during the second sample period and increased through the last two (Figure 4.2). The decrease in average length was countered by an increase in the total numbers of fish captured (Figure 4.2). The most significant contributor to the increase in numbers and decrease in mean length during the second sample period was an influx of YOY lumpfish (Figure 4.1). Lumpfish were caught in 12 of the tidepools during the second sample period, suggesting a widespread arrival, while nine tidepools contained lumpfish in the third sample period. In addition, large numbers of unidentified stickleback fry (a combination of threespine and fourspine) were concentrated in tidepools at the TI site over the second and third sample periods. Large numbers of stickleback fry (threespine, fourspine and ninespine) and YOY mummichog were also abundant through the early summer in shallow estuarine mudflat pools and salt pannes.

The influx of young of year (YOY) lumpfish was followed by a doubling in the number of gunnels in the third sample period and an increase in the number of mummichogs. The mummichog abundance is solely attributable to tidepools at the TI site, the only tidepools to ever contain mummichogs. Although the cause of the fluctuations in the number of mummichogs is partially due to changes in abundance due to YOY fish being sampled, there is also a role of freshwater discharge and other nearshore physical processes (storms, currents, tides) that alter their distribution. Gunnels were found in 13 tidepools during the third sample period. Atlantic snailfish, although not as variable in their abundance across the sample periods, increased in numbers over the course of the season and were most abundant in the last sample period. The short-horned sculpin also become relatively more numerous than the other species, largely due to the declining total number of fish captured.

D. Salt panne tidepools

Salt pannes are a special case of tidepools that are located within estuarine salt marsh environments, and that are in need of further study. We sampled a number of these locations during the estuarine component of this study. The dominant species were young fourspine and ninespine sticklebacks and mummichogs of varying ages. An occasional eel and a number of dead Atlantic silversides (*Menidia menidia*) were also noted. These small and extreme environments often remained beyond tidal influence for a week or more and were exposed to solar heating. In some cases, the temperatures of the pannes and tidal flats were found to exceed 30°C, surely reducing the oxygen levels. These components of estuarine habitats appear to have been underestimated with regards to their contribution to estuarine production in Maine (Michelle Dionne, Wells National Estuarine Research Reserve, personal communication).

Table 4.1. General taxonomic information of fish caught during the tidepool survey on Mount Desert Island and Schoodic Peninsula.

Common Name	Abbreviation	Scientific Name	Order	Family
Pollock	POVI	*Pollachius virens*	Gadiformes	Gadidae
Mummichog	FUHE	*Fundulus heteroclitus*	Cyprinodontiformes	Fundulidae
Threespine stickleback	GAAC	*Gasterosteus aculeatus*	Gasterosteiformes	Gasterosteidae
Fourspine stickleback	APQU	*Apeltes quadracus*	Gasterosteiformes	Gasterosteidae
Longhorn sculpin	MYOC	*Myoxocephalus octodesemspinosus*	Scorpaeniformes	Cottidae
Short-horned sculpin	MYSC	*Myoxocephalus scorpius*	Scorpaeniformes	Cottidae
Grubby	MYAE	*Myoxocephalus aenaeus*	Scorpaeniformes	Cottidae
Sea raven	HEAM	*Hemitripterus americanus*	Scorpaeniformes	Hemitripteridae
Rock gunnel	PHGU	*Pholis gunnellus*	Perciformes	Pholidae
Lumpfish	CYLU	*Cyclopterus lumpus*	Scorpaeniformes	Cyclopteridae
Atlantic snailfish	LIAT	*Liparis atlanticus*	Scorpaeniformes	Liparidae
Winter flounder	PLAM	*Pseudopleuronectes americanus*	Pleuronectiformes	Pleuronectidae

Table 4.2. Description and distinctive characteristics of fish species caught during the tidepool survey.

Common Name	Transient/ Resident[1]	Pelagic/ Benthic	Body form[2]	Max length[3] (cm)		Adhesive organ[4]	Swim bladder[4]	Air breathing[4]	Antifreeze[4]
Pollock	T	P	C	8.2	105	N	Y	N	N/A
Mummichog	T	B	C	5.4	10	N	Y	Y	N/A
Threespine stickleback	T	B	C	6.9	8	N	Y	N	N/A
Fourspine stickleback	T	B	C	5	6	N	Y	N	N/A
Longhorn sculpin	R	B	D-V	8.9	35	N	Y	N	N/A
Short-horned sculpin	R	B	D-V	12.6	60	N	Y	N	Y
Grubby	R	B	D-V	14.0	20	N	Y	N	N/A
Sea raven	T	B	D-V	16.5	56	N	Y	N	N/A
Rock gunnel	R	B	A	18.0	30	N	N	Y	N/A
Lumpfish	R	B	C	6.9	40	Y	Y	N	N/A
Atlantic sea snail	R	B	A, D-V	10.0	13	Y	N	N	N/A
Winter flounder	T	B	D-V	7.9	57	N	N/R	N	Y

[1] Based on observations from this study and Moring (1989, 1990b, 1993a,b, 2001) and Moring and Moring (1991)
[2] Compressed, C; dorso-ventrally flattened, DV; anguine, A
[3] The maximum length (in the present study = left column, typical of Gulf of Maine = right column
[4] Y = yes, N = no, N/A = not available.
Other information supplied by Collette and Klein-MacPhee (2002) and Froese and Pauly (2006).

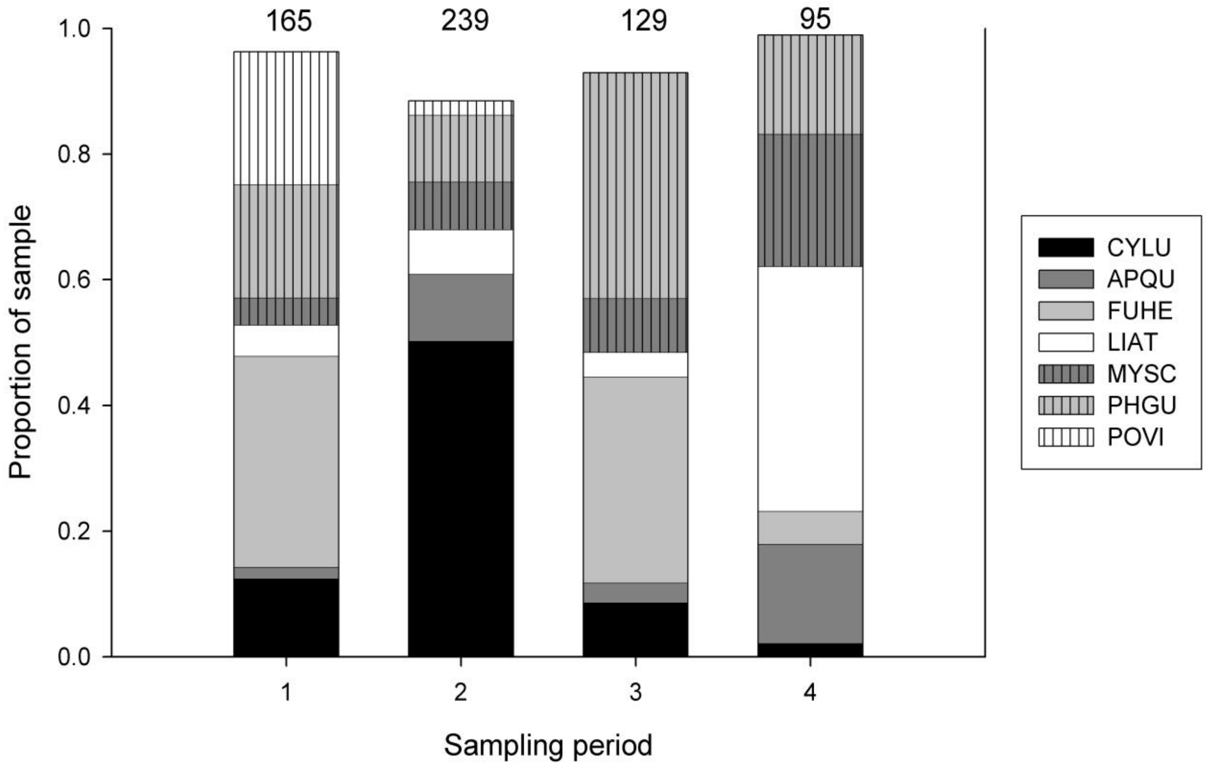

Figure 4.1. Relative proportions of the seven most abundant fish caught during the tidepool survey on Mount Desert Island and Schoodic Peninsula during each sampling period. The total number of fish sampled in each period is given over each stacked bar. See Table 4.1 for description of abbreviations.

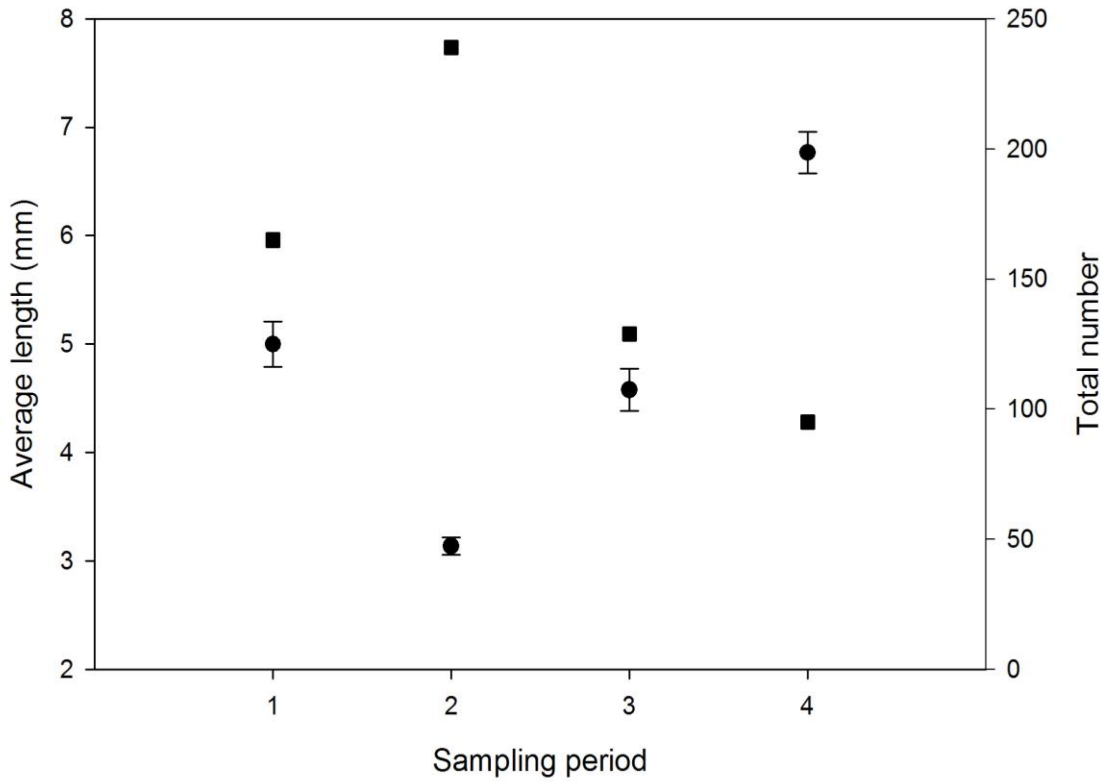

Figure 4.2. Average length of all fish caught (circles, left y-axis) and the total number of fish caught (squares, right y-axis) during the tidepool survey on Mount Desert Island and Schoodic Peninsula during each sampling period

Chapter 5

DEFINING MICROHABITAT-TIDEPOOL FISH CORRELATIONS IN ACADIA NATIONAL PARK

Adrian Jordaan, Jeffrey Crocker and Yong Chen

A. Introduction

Acadia National Park (ANP) receives nearly 3 million visitors annually, largely during the months of July – September. There are competing pressures of tourism and development in and around the park combined with the National Park priority of protecting ecosystem health. Many visitors are attracted to the pristine nature of the coast, which puts organisms that inhabit the intertidal zone at risk of exposure to human activities. Recently there have been changes in management policy at the park designed to protect particular habitats that are susceptible to destruction by human activities. This necessitates the monitoring of ANP's varied ecosystems and the development of assessment techniques that can be integrated into management decisions.

Tidepool fishes are those that inhabit tidepools at low tide and for that reason are isolated in an area that may experience frequent disturbances. These fish include those that inhabit tidepools for much of their life cycle, those who use tidepools as refugia during juvenile stages, and those that are accidentally stranded in tidepools during low tide. Intertidal areas are also particularly susceptible to oil spills, sewage and chemical pollutants released into coastal areas, as well as coastal development (Moring 1983). Strong associations between fish species and tidepool invertebrates and algae, many of which are sessile, mean that fish may be indirectly harmed if these sessile species are damaged during a disturbance.

A first step in the conservation and protection of natural resources is describing the distribution of organisms and their associated habitats. Moring (1993a) described the tidepool fishes that are found along the coast of Maine. We are interested in the characteristics of tidepools that makes them suitable for fish to use. Microhabitats are subsections or finer subdivisions of a habitat, in this case tidepools, in which an animal lives (Kramer et al. 1997). No work has been done to quantitatively define what characteristics or microhabitat variables are important for tidepool fish on the coast of Maine. This information is essential if impacts of development are questioned or it becomes necessary to quantify impacts to near shore habitats. The microhabitat variables can be broken into biological (algal and invertebrate abundance) and physical (substrate, temperature, etc.) characteristics.

In this chapter, we examine what microhabitat variables are associated with the presence, absence and abundance of tidepool fishes. The defining characteristics will be used to outline what factors should be made a priority in the protection of the coastline in and around Acadia National Park. We will also discuss the ecological characteristics of these sensitive habitats and how these may influence further research.

B. Statistical methods

In order to analyze many variables, a multivariate statistical technique was employed. Principal components analysis (PCA) is one of the most common data-exploratory multivariate ordination techniques used in ecological studies (Rao 1964, Manly 1991, Jackson 1993, Chen and Harvey 1995). Such a multivariate approach reduces the number of variables, while essential information inherent in the original data is not lost. Principal components analysis was used in this study to derive a set of new variables (principal components or PCs) that explain variation in tidepool fish abundance (F). Multiple PCs are derived for each of the groups of variables (F = fish abundance, A = algal and grass abundance, I = invertebrate abundance and P = physical variables), equal to the number of original variables within each group. However, the first principal component derived for each group (i.e. F1, A1 and I1), explains the greatest amount of variance within the group, with each additional principal component explaining lesser and lesser amounts of the variance. Typically, only the first few principal components are considered since they explain the majority of the variance; the remaining PCs are of little value and are thus not reported. The analysis was completed in SYSTAT™ v.10.2.

The data were grouped into four sampling periods representing (1) late spring (June 6 – June 26); (2) early summer (July 3 – August 2); (3) late summer (August 3 – September 18); and (4) early fall (September 29 – October 21) to determine seasonal patterns in fish species abundance relative to the changes in microhabitats over the sampling periods. All data are found in Appendices 1-4. Sample sizes were 39, 39, 38 and 39 for sample periods 1, 2, 3 and 4, respectively.

Physical variables recorded are listed in Table 5.1. Tidepools were measured across the longest axis for length (L), then measured perpendicular to this axis at the midpoint of L for the width (W). Tidepool area was calculated by L x W. Depth was calculated by making transects along the L and W axes and averaging the measurements for each. Vertical height was scored as: 1 = tidepool covered by tides lower than mean low tide level; 2 = tidepool only covered by tides higher than mean low tide level; and 3 = tidepools exposed at every tide. The time was recorded when sampling was initiated. Tide height was the expected low tide value for the sampling period, in meters above or below mean low tide level.

Bottom type was assigned for the dominant benthic surface (bedrock, boulders, stones, cobble, gravel, sand or mud). Each different substrate encountered, and additional nooks, cracks, overhangs, erratic corners, shaded areas, convoluted edge and vegetative cover, counted towards a combined measure of physical complexity. Algal cover (in pool and bottom) were scored as < 25%, 25-50%, 50-75%, 75-95% and > 95%. The above measures were summed for a measure of complexity and a resulting range of 1 – 9, with 1 being the most simple single substrate tidepool and 9 having multiple substrates and an irregular shape with substantial cover.

Other physical variables were recorded but not used in the presented analysis. Whether rain was recorded in the last 12 h was noted, as well as the light and wind conditions. Light condition was scored on a scale: 0 = clear conditions, 1 = partly cloudy, 2 = overcast, 3 = fog, 4 = light overcast with drizzle and 5 = heavy overcast with showers. Wind was scored on a scale: 0 = calm, 1 = light air movement, 2 = light breeze, 3 = gentle breeze (leaves in constant motion), 4 = fresh breeze (small trees/bushes moving) and 5 = strong breeze (large branches in motion).

Fish abundance was calculated by taking the number of fish of each species captured in each tidepool and square root transforming the value to meet statistical assumptions of normality. Then the number was standardized by dividing the values by the average number of that species of fish captured across all tidepools. The biological variables collected during the tidepool inventory are given in Table 5.2. The relative abundance of each algal, grass, and hard and soft invertebrate species or group of species was described for each tidepool by assigning an abundance score from 0 to 5. The scoring system was based roughly on percentage cover with 0 identifying that none were present, 1 representing one or two individuals, 3 representing a common species within the tidepool and 5 representing a dominant species in the tidepool, covering much of the available space. Scores of 2 and 4 allowed for moderately common (e.g. 20% of surface covered by barnacle growth) and moderately dominant species to be distinguished from scores of 3 and 5. Invertebrate and algal relative abundances were natural-log transformed and standardized after adding one to the abundances. This technique does assume that species that are observed during repeated trips within the same pool will be represented accurately in relation to one another.

To evaluate the patterns or relationships among the fish, invertebrate, algal, and physical principal components (PC), we calculated Pearson multiple pair-wise comparison tests using Bonferroni-corrected p-values were calculated for each sample period; 4 comparisons for period 1 (significant $p < 0.0125$), 21 comparisons for period 2 (significant $p < 0.002381$), 13 for period 3 (significant $p < 0.003486$), and 19 for period 4 (significant $p < 0.002632$). This resulted in a matrix of correlation coefficients and p-values for each of the principal components. To determine which PC scores to include in the correlation analysis, we used the scree plot technique discussed by Jackson (1993) as the stopping rule. Because the scree plot technique does tend to overestimate the number of interpretable components (Jackson 1993), we were particularly conservative in deeming a component as non-trivial. Still, this is an improvement over the Kaiser-Guttman approach (acceptance of eigenvalues over 1.0 as relevant components), which vastly overestimates the number of interpretable components (Jackson 1993).

C. Results

The principal component analysis and scree plot method determined 4, 8, 6 and 7 interpretable components for sampling period 1, 2, 3 and 4, respectively. For sample 1, A1, I1, F1 and F2 were deemed interpretable and explained 39.1%, 29.8%, 35% and 25% of the total variance, respectively. For sample 2, the interpretable components (with the % of total variance in parentheses) were: F1 (31.1%), F2 (25.6%), A1 (35.5%), I1 (20.1%), I2 (13.4%), I3 (11.5%), I4 (10.0%), and P1 (27.4%). For sample 3, the interpretable components (with the % of total variance in parentheses) were: F1 (35.2%), F2 (23.3%), A1 (41.6%), I1 (25.3%), I2 (13.5%) and P1 (27.0 %). For sample 4, the interpretable components (with the % of total variance in parentheses) were: F1 (35.0%), F2 (24.7%), A1 (32.3%), I1 (22.3%), P1 (24.8%), P2 (19.2%) and P3 (18.0%).

The first sampling period results demonstrated a significant positive correlation of 0.76 between A1 and I1 ($p < 0.001$). In the second sampling period, the Pearson pairwise comparisons demonstrated a significant positive relationship (0.66, $p < 0.001$) between the A1 and I1 principal components, and a positive relationship (0.50, $p = 0.0012$) between I1 and F1. For the third sampling period, there were significant relationships between the first principal components of all variable groups. F1 and A1 ($r = 0.52$, $p = 0.0011$), I1 ($r = 0.60$, $p < 0.001$) and P1 ($r = -0.52$, $p = 0.0014$). There was also a significant relationship between A1 and I1 ($r = 0.60$, $p < 0.001$), and a significant negative correlation between A1 and P1 ($r = -0.58$, $p = 0.0002$). In the fourth sampling period, the significant correlations were between A1 and I1 ($r = 0.48$, $p = 0.0025$), A1 and P2 ($r = 0.49$, $p = 0.0021$), A1 and F1 ($r = 0.59$, $p > 0.0001$), and F1 and I1 ($r = 0.51$, $p > 0.0001$).

To understand the relative importance of the original individual variables in each of the derived principal components, we examined the eigenvector scores. In Period 1, all algal species observed except Enteromorpha had positive scores, suggesting that tidepools either had few algal species present or most of them in some combination. The invertebrates in Period 1 followed the same trend seen in the algae, with only shrimp receiving a negative score. From the eigenvector scores it can be seen that, in Period 2, the macro algae, *Laminaria*, *Ascophyllum* and fucoid species, dominate A; the limpet, crab, and a number of other species dominate I1, and F1 separates the stickleback species from all the other species sampled (Table 5.4). In sampling period 3, F1 reflects the negative association between most of the fish species with sticklebacks and mummichogs. Principal components A1 and P1 remained much the same as A1 and P2 in period 2, although relative position had a greater influence in P1 (Table 5.5). There is no change in the important contributors to the principal components generated for the fourth sampling period (Table 5.6). Other important trends in the eigenvectors for Period 4 are (1) that pollock and grubbies had lower impacts on the F1 scores, (2) the A1 eigenvectors are highest for the large fucoid and kelp species, which occur together in highly species diverse lower pools, and lowest for *Enteromorpha sp*. and other less diverse pool species (crustose algae), and (3) generally eigenvectors for I1 were all positive, except the periwinkle was negative and among the lowest scoring invertebrate species.

D. Discussion

Two important trends were apparent from the principal component analyses of the fish data. First, the first principal component (F1) explains a greater amount of the variance in fish abundance over each successive period until a slight drop in Period 4. In addition, the first four principal components explain less of the variability in fish abundance in Period 1 than in the other periods. That is, fish abundance became more predictable over the course of the study (Figure 5.1). The predictability speaks to the increased likelihood that species will be captured together in later sample periods and somewhat more randomly dispersed in sample period 1. It is also worth noting that at least one fish principal component is significantly correlated with algae, invertebrate, or physical principal components in all periods except Period 1. This suggests that fish abundance may be more predictable in later time periods.

Second, in all the sample periods there was a clear trend in the groupings of fish species where mummichogs (FUHE) and fourspine sticklebacks (APQU), with the threespine stickleback (GAAC) and unidentified stickleback fry in period 2, separated from the other species of tidepool fish, particularly in the first component (e.g., Figure 5.2). The fish principal components showed that there were three primary types of tidepools, those where: (1) fish are absent, (2) mummichogs and sticklebacks are present, and (3) all other fish are present. It is also important to note that tidepools that were depauperate in algal species, were also limited in invertebrates and fish species. This trend was likely strongly related to the tidepool position relative to mean tide height, although the mudflat tidepools also had reduced species of algae and invertebrates. The second separation of species is largely controlled by the presence of the two different tidepool habitats around Acadia National Park: rocky ledges and mudflats. The two groupings of fish were clearly separated along these lines and there appears to be little overlap. To determine finer scale associations, studies over transition zones between the two primary habitat types would be required. Within the cluster of tidepools with the majority of fish species (positive values in the F1 eigenvectors), the pollock and grubby were grouped to a lesser degree than the lumpfish, snailfish and short-horned sculpins. For the grubby this result may originate from its higher temperature tolerance (Collette and Klein-MacPhee 2002) and the presence of the species in relatively shallow tidepools with reduced complexity. For pollock, which have been identified as a part-time transient species (Chapter 5), the looser relationship may stem from a more unpredictable occurrence based on the probability of being caught in tidepools during the ebbing tide.

The important physical parameters were always associated with vertical position relative to tide height; including time which had an effect on the tide height and tidepools that could be sampled. This is a possible bias. Generally, relative position of the tidepool influenced the physical principal component in the same direction as temperature and tidal height and in the opposite direction as salinity. This relationship among variables suggests that as relative position increases, the temperature increases and salinity decreases. This relationship was modified by the tidal height, which was entered as the distance below mean tide level (a negative number). Higher low tides resulted in reduced temperatures and increased salinities because of an increased marine influence. The interaction between the marine environment (lower temperatures and higher salinities) and the terrestrial environment (higher temperatures, lower salinities) is clearly influencing the distribution of organisms. Furthermore, the terrestrial environment can be a source of drier or wetter conditions, therefore trends in physical factors may vary during different years under different climatic influences. It is on this initial condition that tidepool communities are founded. Conditions in the high intertidal zone are likely variable from year-to-year, with wet years producing cooler and less saline conditions on average and dry years producing warmer and more saline conditions on average. Furthermore, because patterns may change throughout the year, it is likely that these types of differing patterns could be observed within one year.

Vertical zonation of species in the intertidal zone has been shown on the coasts of most continents (Zander et al. 1999). This pattern was evident in the third sampling period where A1 and I1 were both strongly correlated with the physical parameters involved in the vertical position of the tidepool. Enteromorpha scored a negative value and is common in tidepools high in the intertidal zone, and this contrasted with the other species which are all found lower in the intertidal zone. As the year progressed, biological associations slowly replaced the initial physical-biological coupling restricted to lower trophic levels early in the year. That is, the associations amongst the invertebrate and fish species replaced those amongst physical variables and algal species as the significant correlations in tidepools. We believe that periods of strong biological associations are the times where alterations to the tidepool by physical (storm events) and anthropogenic (oil spills) disturbances will most affect the presence of fish species.

Fish species were related to vertical height in the present analysis, but not in every sample period. The only species that are not vertically restricted are the mummichog and threespine stickleback, since both are found extensively across salt marsh surface (Jordaan, Personal Observation), as well as in mudflat tidepools. All other species are related to the vertical position because they do not occupy the highest tidepools. Rock gunnels were capable of inhabiting depauperate pools high in the intertidal zone, but this did not occur that often. In sample period 3, when fish distributions have become most predictable, physical variables related to the vertical height are correlated to the first principal components of the algal, invertebrate and fish groups. The loadings suggest that most species (diversity) is directly related to the height of the tidepool, and that structuring is correlated across taxa and trophic levels.

From the algal and invertebrate comparisons, the most important parameters appeared to be the presence of macroalgae for the algae and the presence of whelks, crabs, limpets, seastars, isopods, and nudibranchs for the invertebrates. Sea cucumbers and brittle stars are important variables in the fourth sampling period, but are not in any others. Trait-mediated effects between rock crabs, periwinkles, and fucoid algal communities have been documented (Trussell et al. 2002). The green crab (*Carcinus maenas*) has been described as a eurytopic voracious generalist predator (Lafferty and Kuris 1996) whose prey consists of most predominant macrobenthic invertebrates (Ropes 1968). The presence of the crab reduces periwinkle grazing on fucoid algae by either direct predation or through water-born cues that influence grazing activity in the periwinkles (Trussell et al. 2002). Our results support other studies showing that the relationships among these groups play important roles in structuring tidepool communities. The presence of crabs (and to some degree the absence of periwinkles) and other predators (seastars, whelks) is correlated with the presence of the macroalgae, particularly early in the season. Trussell et al. (2002) suggest that the grazing of periwinkles on fucoid algae is most important early in the season when the algal fronds start to grow and that interactions between the two appear to strongly influence the algal community in terms of structure and succession. Later in the season, during Period 4, the correlation coefficient between A1 and I1 was still near 0.5 but no longer significant ($p \sim 0.15$). The relationship among these variables and F1 suggest an important role of biological characteristics of the tidepool early in the year, and their physical conditions such as relative height of the tidepool to the sea level, in structuring the eventual fish community.

It is important to note that both the periwinkle (*Littorina littorea*) and the green crab are invasive species from Europe. The presence of these two species in tidepools is a sign that invasive species could have a dramatic influence on ecology of these ecosystems. Interactions between community members will likely be again altered by the imminent invasion of the Japanese shore crab (*Hemigrapsus sanguineus*), which has been spreading northward and is now present in Penobscot Bay. Monitoring efforts should concentrate of identifying these species and attempting to document their effects.

Disturbances play a major role in determining intertidal species composition (Underwood 1999). However, disturbances occur over a range of temporal and spatial scales. At the smallest scale there is human physical disturbance of tidepools around Acadia. This effect was seen at the Anemone cave site, where long-term visitation has apparently reduced the invertebrate populations. These sites were depauperate in fish species with only one specimen (short-horned sculpin in Period 3) ever caught there. A strong wind event on August 7, 2001 (wind gusts of 50 mph, NOAA) resulted in large swells and falling ocean temperatures during Period 4 (Figure 3.3). This event may have contributed to changes in the distribution of fish species in the intertidal zone.

In terms of management of the National Park, the most important disturbance is anthropogenic habitat alteration. Our findings suggest that changes to the coastal geomorphology and to the balance of sedimentation and erosion along the coast could have dramatic influences on the overall community assemblage. If coastal construction allows either higher than expected sedimentation rates along rocky coastal regions or higher than expected erosion in mudflat habitats, then we would expect dramatic changes in flora and fauna of tidepools. However, although there are some specific exceptions, we believe that Acadia's tidepools are generally immune to most disturbances from direct human pressure because of their abundance along remote and inaccessible coastline.

Table 5.1. Physical variables collected for each tidepool and whether the variable was included in the PCA.

Variable	Units	Included in analysis
Pool Length	cm	No
Pool Depth	cm	No
Pool Area (Length X Depth)	cm^2	Yes
Substrate type	(rock, mud, etc)	Yes
Physical complexity	Combined measure	Yes
Vertical Height	Relative position	Yes
GPS	UTM	No
Algal Cover (top)	Estimated %	No
Algal Cover (bottom)	Estimated %	No
Temperature	Celsius	Yes
Salinity	parts per thousands	Yes
Tidal Height	m	Yes
Rain	Relative scale	No
Wind	Relative scale	No
Lighting	Relative scale	No

Table 5.2: Biological variables collected for each tidepool. Each of the listed species, or groups of species, was given a relative abundance score from 1 - 5

Algae and grasses		
Eel Grass	Brown thread like	Sea Lettuce
Spartina spp.	Irish Moss	Green Fuzzy
Algae	Sugar kelp	Purple laver
Ascophyllum	Horse kelp	Dulse
Rockweed Fucus	Edible kelp	Coraline crust
Brown fuzzy algae	Maidenhair	Coraline 3-D
Hard Invertebrates		
Barnacle	Limpet	Hermit Crab
Mussel	Sponge	Sea star
Periwinkle	Crab	Urchin
Whelk		
Soft invertebrates		
Amphipod	Scaleworm	Cucumber
Isopod	Worm-like	Eggs
Nudibrach	Anemone	Shrimp

Table 5.3. Eigenvector scores for principal components that demonstrated significant relationships for Period 1

A1		I1	
ASCOPHYLLUM	0.554618	BARNACLES	0.411598
FUCUS	0.843885	MUSSELS	0.569001
BROWNFUZZ	0.781349	PERIWINKLES	0.552806
BROWNTHREAD	0.354474	WHELK	0.752044
IRISHMOSS	0.736923	LIMPET	0.74451
SUGARKELP	0.76153	SPONGE	0.527275
HORSETAILKE	0.643793	CRAB	0.571692
EDIBLEKELP	0.43347	HERMITCRAB	0.668382
ENTEROMOPH	-0.02831	SEASTAR	0.699377
SEALE			
TTUCE	0.745235	BRITTLESTAR	0.290337
GREENMISC	0.544916	URCHIN	0.58506
PURPLELAVER	0.451207	AMPHIPOD	0.64137
DULSE	0.68012	ISOPOD	0.634468
CORALINECRUS	0.694749	NUDIBRANCH	0.5511
CORALLINE3D	0.701348	SCALEWORM	0.419567
ASCOPHYLLUM	0.554618	WORMLIKE	0.52266
FUCUS	0.843885	ANEMONE	0.355161
		SEACUCUMBER	0.036128
		EGGS	0.615224
		SHRIMP	-0.00284

Table 5.4. Eigenvector scores for principal components that demonstrated significant relationships for Period 2

A1		I1		F1	
SUGARKELP	0.369	LIMPET	0.414	PHGU	0.412451
IRISHMOSS	0.313	CRAB	0.384	CYLU	0.632596
HORSETAILKE	0.313	NUDIBRANCH	0.317	LIAT	0.618229
DULSE	0.306	ISOPOD	0.309	POVI	0.475777
FUCUS	0.303	SEASTAR	0.301	MYSC	0.211226
BROWNFUZZ	0.300	WHELK	0.287	MYAE	0.48726
ASCOPHYLLUM	0.286	SHRIMP	0.272	HEAM	0.701541
SEALETTUCE	0.274	BARNACLES	0.055	APQU	-0.63761
GREENMISC	0.270	ANEMONE	-0.078	GAAC	-0.6392
CORALLINE3D	0.245	HERMITCRAB	0.260	PLAM	0.502853
EDIBLEKELP	0.221	MUSSELS	0.003	STICKLEFRY	-0.6315
EELGRASS	0.077	PERIWINKLES	-0.025		
SPARTINA	0.077	BRITTLESTAR	0.014		
BROWNTHREAD	0.019	URCHIN	0.120		
PURPLELAVER	-0.008	AMPHIPOD	0.175		
CORALINECRUS	0.181	EGGS	0.077		
ENTEROMOPH	-0.090	SEACUCUMBER	-0.054		
		WORMLIKE	0.151		
		SCALEWORM	0.216		
		SPONGE	0.191		

Table 5.5. Eigenvector scores for principal components that demonstrated significant relationships for Period 3

F1		A1		I1		P1	
GAAC	-0.509	SUGARKELP	0.319	WHELK	0.382	TIDEHEIGHT	0.545
APQU	-0.507	FUCUS	0.316	LIMPET	0.362	TEMP	0.471
FUHE	-0.504	BROWNFUZZ	0.313	CRAB	0.360	TIME	0.393
LIAT	0.248	IRISHMOSS	0.298	SEASTAR	0.282	SAL	-0.342
CYLU	0.222	CORALINECRUS	0.288	SCALEWORM	0.280	RELPOSITION	0.326
PHGU	0.233	BROWNTHREAD	0.282	HERMITCRAB	0.245	AREA	0.040
MYAE	0.061	HORSETAILKE	0.281	SHRIMP	0.235	PHYSCOMPLEX	-0.243
MYSC	0.211	CORALLINE3D	0.265	BARNACLES	0.231	DEPTH	-0.116
POVI	0.128	DULSE	0.257	ISOPOD	0.125	SUBSTRATE	0.173
		GREENMISC	0.243	URCHIN	0.225		
		ASCOPHYLLUM	0.222	BRITTLESTAR	0.003		
		EDIBLEKELP	0.212	WORMLIKE	0.063		
		ENTEROMOPH	-0.133	EGGS	-0.029		
		PURPLELAVER	0.087	NUDIBRANCH	0.208		
		SPARTINA	-0.131	AMPHIPOD	0.138		
		SEALETTUCE	0.195	SPONGE	0.178		
				ANEMONE	0.209		
				PERIWINKLES	0.128		
				MUSSELS	0.205		

Table 5.6. Eigenvector scores for principal components that demonstrated significant relationships for Period 4

F1		A1		I1		P2	
MYSC	0.452	SUGARKELP	0.343	SEACUCUMBER	0.366	PHYSCOMPLEX	0.866
LIAT	0.412	BROWNFUZZ	0.34	BRITTLESTAR	0.36	AREA	0.718
FUHE	-0.406	FUCUS	0.328	HERMITCRAB	0.331	SUBSTRATE	0.469
APQU	-0.38	SEALETTUCE	0.318	ISOPOD	0.323	TIME	0.429
CYLU	0.359	CORALLINE3D	0.318	LIMPET	0.316	TEMP	0.112
PHGU	0.355	BROWNTHREAD	0.315	CRAB	0.307	TIDEHEIGHT	0.096
MYAE	0.249	HORSETAILKE	0.305	NUDIBRANCH	0.304	SAL	-0.012
		EDIBLEKELP	0.228	SEASTAR	0.294	RELPOSITION	-0.075
		IRISHMOSS	0.106	URCHIN	0.102	DEPTH	-0.166
		CORALINECRUS	0.19	MUSSELS	0.023		
		PURPLELAVER	0.112	BARNACLES	0.081		
		DULSE	0.227	PERIWINKLES	-0.126		
		GREENMISC	0.203	AMPHIPOD	0.136		
		ENTEROMOPH	0.116	SCALEWORM	0.113		
		ASCOPHYLLUM	0.217	WHELK	0.2		
				ANEMONE	0.078		
				SPONGE	0.169		
				SHRIMP	0.1		

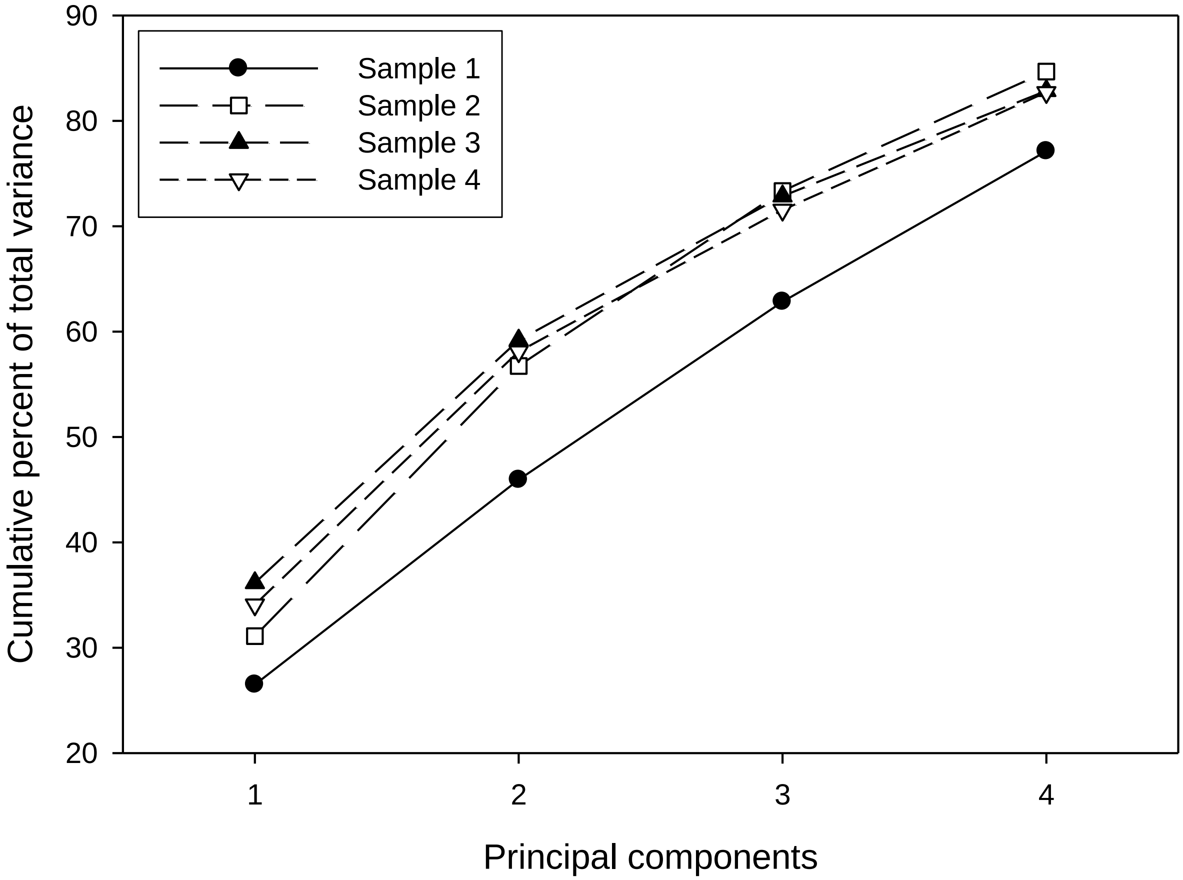

Figure 5.1. Cumulative percent of variance in fish species abundance explained by the first four principal components (F1-F4) over sampling Periods 1-4. Note: 0-20% and 90-100% has been excluded from y-axis for greater visual acuity.

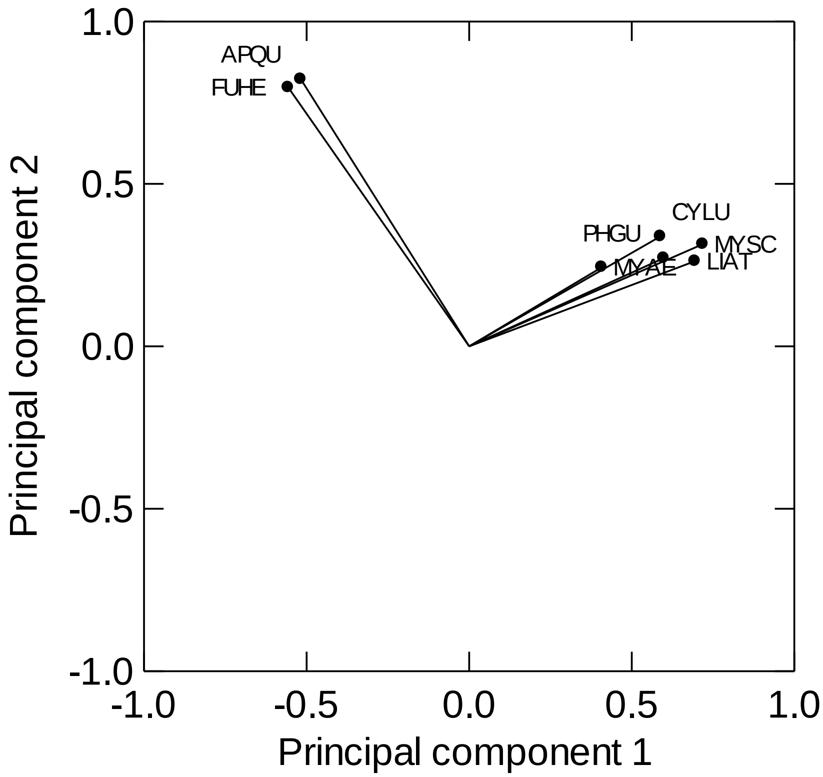

Figure 5.2. Plot of first two principal components from the analysis of the fish data in the fourth sample period. CYCL = lumpfish, LIAT = snailfish, MYAE = grubby, MYSC = short-horned sculpin, PHGU = rock gunnel, FUHE = mummichog, APQU = fourspine stickleback

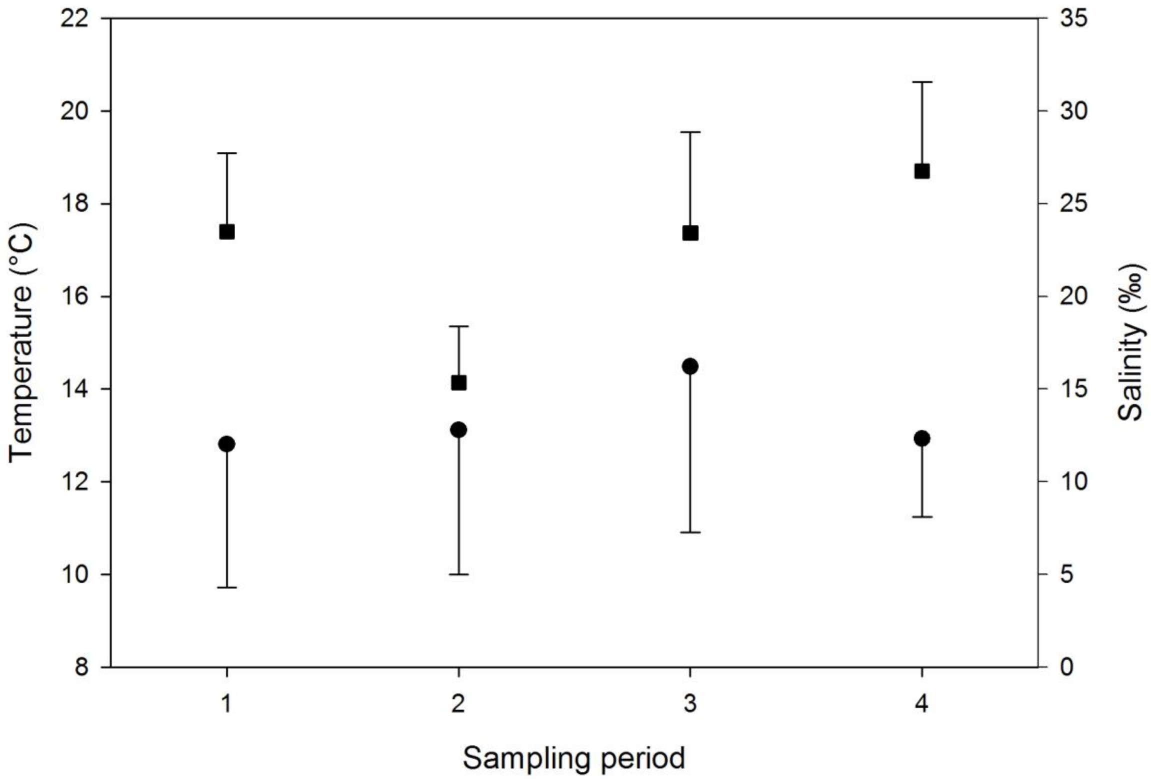

Figure 5.3. Average temperature (circles, left axis) and salinity (squares, right axis) over the four sampling periods. Error bars = standard deviation.

Chapter 6

INVENTORY OF ESTUARINE FISHES IN ACADIA NATIONAL PARK

Adrian Jordaan, John Speirs, Natasha Hussey and Linda Kling

A. Introduction

This chapter describes the estuaries surveyed and enumerates the fish species captured. Five estuaries were inventoried: Seal Cove, Somes Sound, Bass Harbor, Northeast Creek, and Mosquito Cove. Four of the estuaries are located on Mount Desert Island (MDI), and one of the estuaries is located on adjacent Schoodic Point. A list of the fish species caught during the estuary survey is presented in Table 6.1.

The majority of the fieldwork took place between June 13, 2002 and August 21, 2003. In 2002, mostly minnow traps were used, but were supplemented with fyke nets, dip nets and beach seines. In 2003, beach seines were employed; the other techniques were abandoned because of the more complete sampling achieved using seines compared to other methods. The date, time, gear used and exact location of the survey with the number of each fish species caught are presented in appendices. A summary of the fish species caught in 2002 is found in Table 6.2 and in 2003 in Table 6.3. When no number appears on the row, no fish were captured but the effort was made. Additional information on the length of the fish captured and other biota inventoried for the estuaries are presented in appendices.

Table 6.1. Checklist and taxonomic information of each species caught during estuarine survey of Mount Desert Island and Schoodic Peninsula. Included are abbreviations used in figures.

Common Name	Scientific Name	Abbrev	Order	Family
Mummichog	*Fundulus heteroclitus*	FUHE	Cyprinodontiformes	Fundulidae
Threespine stickleback	*Gasterosteus aculeatus*	GAAC	Gasterosteiformes	Gasterosteidae
Fourspine stickleback	*Apeltes quadracus*	APQU	Gasterosteiformes	Gasterosteidae
Ninespine stickleback	*Pungitius pungitius occidentalis*	PUPU	Gasterosteiformes	Gasterosteidae
American eel	*Anguilla rostrata*	ANRO	Anguilliformes	Anguillidae
Atlantic silverside	*Menidia menidia*	MEME	Atheriniformes	Atherinopsidae
Lumpfish	*Cyclopterus lumpus*	CYLU	Scorpaeniformes	Cyclopteridae
Atlantic mackerel	*Scomber scombrus*	SCSC	Perciformes	Scombridae
Rock gunnel	*Pholis gunnellus*	PHGU	Perciformes	Pholidae
Alewife	*Alosa pseudoharengus*	ALPS	Clupieformes	Clupeidae
Hardhead sea catfish	*Ariopsis felis*	ARFE	Siluriformes	Aridae
Banned killifish	*Fundulus diaphanous*	FUDI	Cyprinodontiformes	Fundulidae
Cunner	*Tautogolabrus adspersus*	TAAD	Perciformes	Labroidae
Blackspotted stickleback	*Gasterosteus wheatlandi*	GAWH	Gasterosteiformes	Gasterosteidae
Atlantic herring	*Clupea harengus*	CLHA	Clupieformes	Clupeidae
Northern pipefish	*Syngnathus fuscus*	SYFU	Gasterosteiformes	Syngnathidae
Inshore sandlance	*Ammodytes americanus*	AMAM	Perciformes	Ammodytidae
Golden shiner	*Notemigonus crysoleucas*	NOCR	Cypriniformes	Cyprinidae
Blueback herring	*Alosa aestivalis*	ALAE	Clupieformes	Clupeidae
Short-horned sculpin	*Myoxocephalus scorpius*	MYSC	Scorpaeniformes	Cottidae
Grubby	*Myoxocephalus aenaeus*	MYAE	Scorpaeniformes	Cottidae

Table 6.2. Summary of the number and percentage of individual species caught during the 2002 estuary survey pooling all gear types within location and sampling periods. See Table 6.1 for description of abbreviations. Note that Mosquito Cove had two species not observed in the other estuaries.

	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
Seal Cove														
TOTAL	902	1	82	0	3	3	0	1	0	61	1	0	1	0
%	85.5	0.1	7.8		0.3	0.3		0.1		5.8	0.1		0.1	
Somes Sound														
TOTAL	1770	20	0	20	16	712	0	0	2	1	0	0	0	0
%	69.7	0.8	0.0	0.8	0.6	28.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Bass Harbor														
TOTAL	2010	327	113	46	7	283	0	0	0	41	0	0	0	43
%	70.0	11.4	3.9	1.6	0.2	9.9	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.5
Northeast Creek														
TOTAL	3291	9	32	68	36	25	0	0	0	1	0	1	0	0
%	95.0	0.3	0.9	2.0	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mosquito Cove											MYSC	MYAE		
TOTAL	122	0	0	0	2	29	34	3	0	0	1	1	6	0
%	61.6				1.0	14.6	17.2	1.5			0.5	0.5	3.0	

Table 6.3. Summary of the number and percentage of individual species caught during the 2003 estuary survey pooling all gear types within location and sampling periods. See Table 6.1 for description of abbreviations.

	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
Seal Cove															
TOTAL	256	0	6	0	1	27	1	0	0	0	0	0	0	0	0
%	88.0		2.1		0.3	9.3	0.3								
Somes Sound															
TOTAL	63	423	0	625	19	158	0	0	168	1	4	0	0	290	
%	3.6	24.2		35.7	1.1	9.0			9.6	0.1	0.2			16.6	
Bass Harbor															
TOTAL	449	31	93	84	0	73	0	0	2	180	1	0	11	0	0
%	48.6	3.4	10.1	9.1		7.9			0.2	19.5	0.1		1.2		
Northeast Creek															
TOTAL	1652	31	67	906	2	218	0	0	2	14	0	0	6	9	41
%	56.0	1.1	2.3	30.7	0.1	7.4			0.1	0.5			0.2	0.3	1.4
Mosquito Cove															
TOTAL	130	0	1	34	0	11	0	3	0	0	0	3	0	3	0
%	70.3		0.5	18.4		5.9		1.6				1.6		1.6	

B. Seal Cove

Seal Cove is a small cove on the southwest coast of MDI. Compared to the other sites surveyed, Seal Cove has limited marsh area. A relatively steep topography upstream towards Seal Cove pond and the placement of a culvert at a position relatively high in the tidal zone, contribute to the small area.

For the 2002 survey, minnow trap A was placed at the base of a series of falls that appear at low tide. The grid of minnow traps was placed seaward over a flat with varying substrates (Figure 6.1). A seine, block seine (where the estuary was cut off at high tide and the retained species enumerated), fyke net, and dipnet were also used.

Mummichogs were the most abundant species (85.5%) captured across all gear type (Table 6.2). Fourspine sticklebacks were also consistently captured from June through August albeit at lower numbers (7.8%). Small alewives were observed well up in the estuary at night during a full moon on 08/21/02. In addition a threespine stickleback, a few eels and Atlantic silversides, a sea catfish and a cunner were also captured in the minnow traps or by netting. One Atlantic mackerel was caught by hook and line on 8/23/02.

For the 2003 survey, the three seine stations that were chosen were located in the channel leading into Seal Cove along a rock ledge (Station 1), on the North side within the inner cove on a gravel shoreline (Station 2), and within the upper impoundment of water in a muddy substrate marsh (Station 3, Figure 6.1). The only sampling station that consistently yielded fish was the site within the small impoundment of water upstream from the road culvert. Here, mummichog were abundant representing 88% of all fish captured (Table 6.3). A larger number of Atlantic silversides were captured by seines in 2003, than by minnow traps in 2002, especially during the last sampling on 8/17/03. In addition a few fourspine sticklebacks, an eel and a lumpfish were capture in the seines during 2003.

Just outside Seal Cove, there is a small herring fishery that occurs over a few days during early June, and nets are used to cut off the bay. Fishermen use the cove to moor boats used in the fishery, and in 2004 they added a small moored dock to work from. A trap is used to corral migrating herring schools. We were allowed to accompany the fishermen to collect the catch. Our sub-sample of that catch suggests that migrating herring and an occasional rainbow smelt (*Osmerus mordax*) also inhabit Seal Cove even though they were not captured during our survey during 2002/2203.

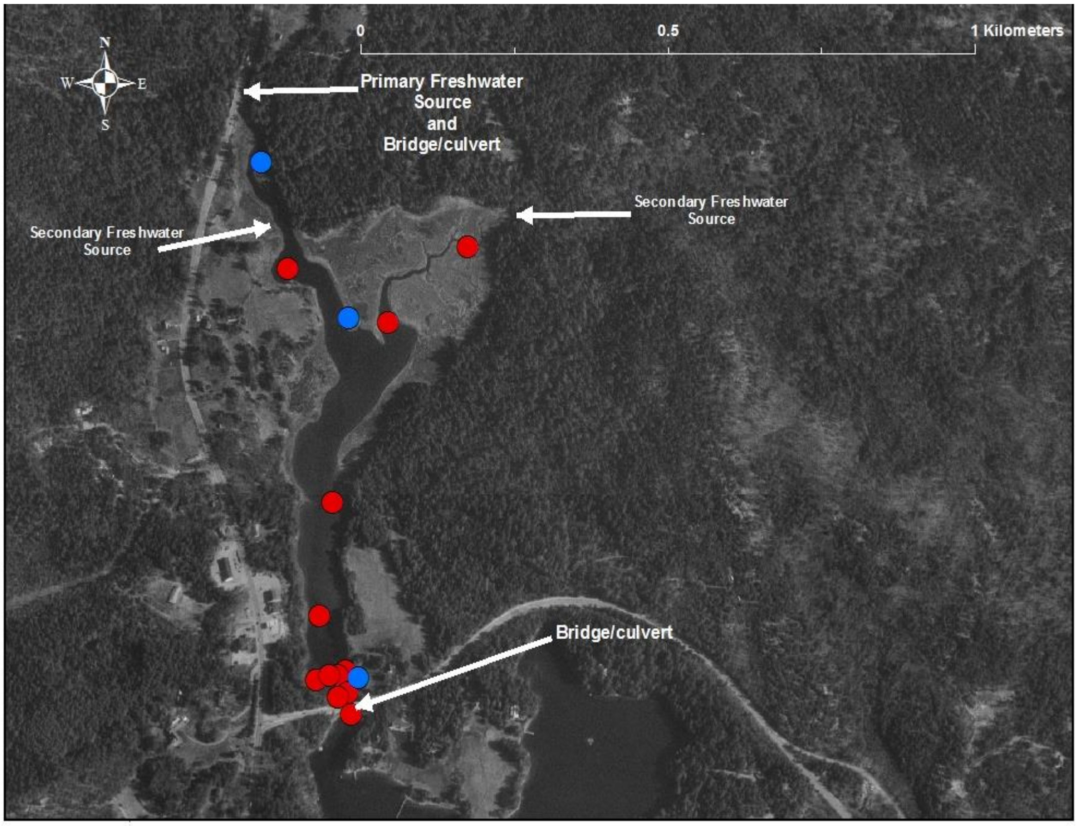

Figure 6.1. Location of 2002 traps (red circles) and 2003 seines (blue circles) relative to culvert and freshwater sources in the Seal Cove estuary. For location of Seal Cove estuary see Figure 2.1.

C. Somes Sound

The Somes Sound estuary is a relatively small estuary at the head of Somes Sound with a small impoundment of water that is maintained by a road crossing (Fig. 6.2). There are two inputs of fresh water; both essentially have no water flow during the driest periods of the year.

Mummichogs were caught in large numbers throughout the 2002 sampling representing almost 70% of all fish captured. Appreciable numbers of Atlantic silversides (712) were captured in September via seines but not in minnow traps. Threespine and ninespine stickleback, American eel each made up less than 1% of the catch with an occasional alewife (1) and rock gunnel (2) (Table 6.2).

In 2003, all the sampling sites were upstream from the bridge, a situation unique to this site. The first sampling station was just upstream of the bridge, along a sandy shoreline that contains only a small fringing marsh. The second station was across a muddy substrate, with the net deployed from a bank of the extensive salt marsh. The third station was in a shallow water channel over a substrate of sand/mud where the marsh has been reduced. A small herring fishery takes place outside of the Somes Sound site (Fig 6.2)

In 2003, seining allowed for a greater variety of species to be captured (Table 6.3). Threespine and ninespine sticklebacks were abundant, making up 24.2 and 35.7% of the total fish captured. Lesser but appreciable numbers of Atlantic silverside (158), alewife (168) and blueback herring (290) were also captured. Mummichog, although consistently present, made up a smaller percentage (3.6%) of the total catch. Eel (19) and an occasional northern pipefish (4) and blackspotted stickleback (1) were also present.

Figure 6.2. Location of 2002 traps (red circles) and 2003 seines (blue circles) relative to culvert and freshwater sources in the Somes Sound estuary. For location of Somes Sound estuary see Figure 2.1.

D. Bass Harbor

The Bass harbor estuary is one of the two large marsh systems present on Mount Desert Island, the other one being Northeast Creek. Doering et al. (1995) provided a comprehensive description of the system.

In 2002, the fyke net position was moved after the first sampling day because the strong flow of water under the bridge interfered with proper deployment (Fig 6.3). Mummichogs were by far the most abundant species captured in 2002 making up 70% of the total fish captured (Table 6.2). Appreciable numbers of threespine (327) and four-spine (113) stickleback and Atlantic silversides (283) were also captured with lesser numbers of ninespine stickleback (46), eel (7), alewife (41) and blackspotted stickleback (43). All of the latter two species were caught during just one sampling episode for each.

In 2003, beach seines were employed and, to cover more of the system, five permanent sampling stations were used as well as one temporary station (Fig 6.3). The first station was located on the ocean side of the bridge from a small ledge over an extensive mudflat. The second station was located on the freshwater side of the bridge, on the east bank, from a small fringing marsh over a cobble/sand and mud substrate. The third station was located on the west bank where an extensive marsh is present and sampling was over a mudflat habitat with substantial macroalgal vegetation. The fourth station was located at a more restricted marsh habitat where the channel begins to meander towards the freshwater sources. The fifth station was located at the beaver dam that essentially acted as the terminus to estuarine conditions. An additional site was added in the final sampling period, between station 4 and 5 (station 4.5), and was located in the heavily meandering section of the marsh channel.

The 2003 survey resulted in fewer fish caught over the survey but similar species were present (Table 6.3). Two noted exception was the capture of a few golden shiners and a northern pipefish. Mummichogs were less abundant (48.6%) and blackspotted sticklebacks were more abundant (19.5%). Eel were absent in the 2003 survey.

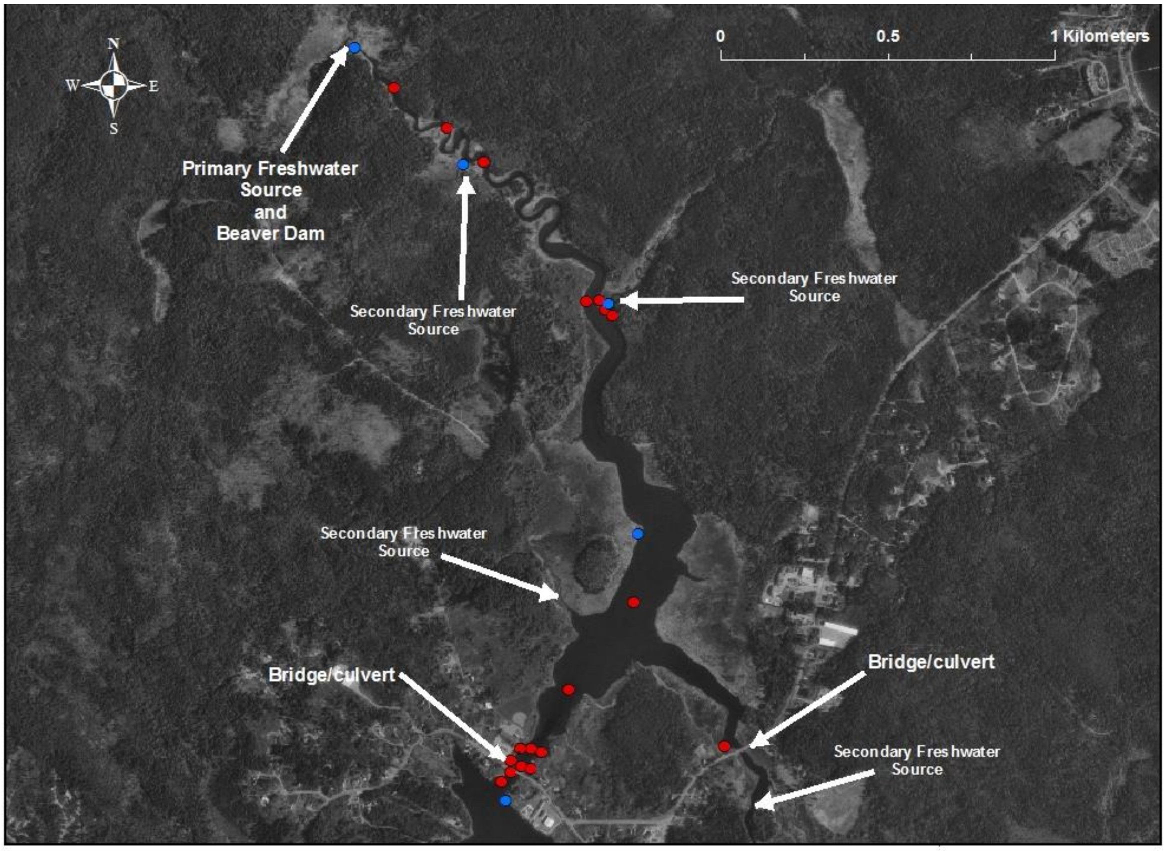

Figure 6.3. Location of 2002 traps (red circles) and 2003 seines (blue circles) relative to culvert and freshwater sources in the Bass Harbor estuary. For location of Bass Harbor estuary see Figure 2.1.

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E. Northeast Creek

This is the second of the two large salt marsh habitats found on Mount Desert Island. Northeast Creek, however, faces north on the lee side of the Island whereas Bass Harbor is found on the more exposed south side of the island and faces south. The location of the bridge is also dramatically different between the two sites, with the Northeast Creek bridge and culvert above the influence of almost all tides (Fig 6.4). Still, the influence of the saltwater received by the higher tides is seen for a mile or so up the river in the form of a dense saltwater plume under the freshwater flow.

In 2002, using mostly minnow traps, mummichog were by far the most abundant species making up 95% of the total fish captured. There were lesser numbers of threespine (9), fourspine (32), and ninespine (68) sticklebacks, and Atlantic silverside (25) each making up less than 2% of the total catch. American eel were quite abundant (36) relative to the other estuary but still only made up 1% of the total catch. A single alewife and banned killifish were also captured (Table 6.2).

In 2003, four sampling stations were used to cover the Northeast Creek estuary (Fig. 6.4). The first two stations were located below the bridge toward the ocean. The first sampling station was from a fringing marsh over a gravel/sand substrate. The second was over mud substrate with fringing marshes. The first on the freshwater side of the bridge was over gravel/sand and mud substrate and stretched across the deeper part of the channel. The final and most freshwater site was well up the creek at a position where prior sampling determined it would be near the limit of the marine influence. This site was over a thick mud bottom within a substantial marsh. Much of the marsh was floating and seine sampling was difficult.

A greater variety of species of fishes were captured during the 2003 survey using seines (Table 6.3). Mummichog continued to be well represented (56%) but greater numbers of ninespine stickleback (30.7%) and Atlantic silversides (7.4%) were present in 2003 than 2002. In addition, banned killifish (41) were quite abundant. In addition to the species caught in 2002, blackspotted stickleback (14), blueback herring (9) and golden shiners (6) were also part of the survey. Eel (2) were much less abundant in the 2003 survey than the 2002 survey.

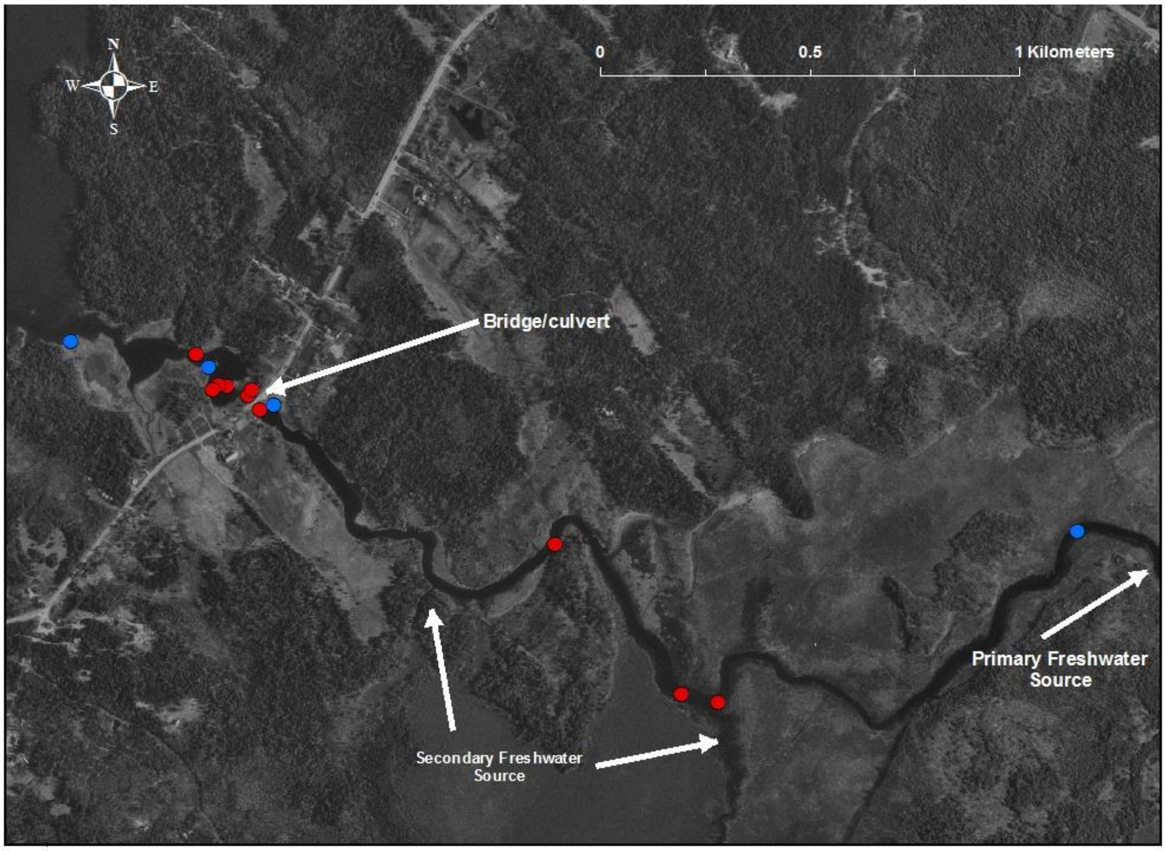

Figure 6.4. Location of 2002 traps (red circles) and 2003 seines (blue circles) relative to culvert and freshwater sources in the Northeast Creek estuary. For location of Northeast Creek estuary see Figure 2.1.

F. Mosquito Cove

Mosquito Cove is a moderate impoundment of water held by the park road. Most of the impounded area drains at low tide, exposing mudflats where active clam digging occurs. Still, some water remains impounded and the natural flow regime is delayed relative to the tides outside the impoundment. There are a number of secondary inputs of fresh water; with limited water flow during the driest periods of the year (Fig 6.5).

In 2002, Mosquito Cove was only sampled during early August. Minnow traps were set but were only modestly successful. Dip netting and angling supplemented the catch. Mummichog again was the most abundant species making up almost 62% of the catch. Unlike the other sites sticklebacks were absent from the survey. Atlantic silversides (14.6%) and lumpfish (17.2%) made up a significant portion of the catch. Eel (2) were present but in low numbers. Also present but in low numbers were cunner (6), short-horned sculpin (1) and grubby (1). Angling caught three Atlantic mackerel (Table 6.2).

In 2003, three sampling sites were upstream from the bridge, and one was below the bridge. The first sampling station was just outside the bridge, along a rocky ledge that contained only a small fringing marsh. The second and third stations were across a muddy substrate, deployed from a bank with limited fringing salt marsh. The fourth station was in a shallow water channel over a substrate of sand/mud with a fringing marsh near the primary freshwater input.

In 2003, using seines, in addition to mummichog, four- and nine-spine stickleback, Atlantic silverside, Atlantic and blueback herring were captured. Unique to this site, three inshore sand lances were caught (Table 6.3).

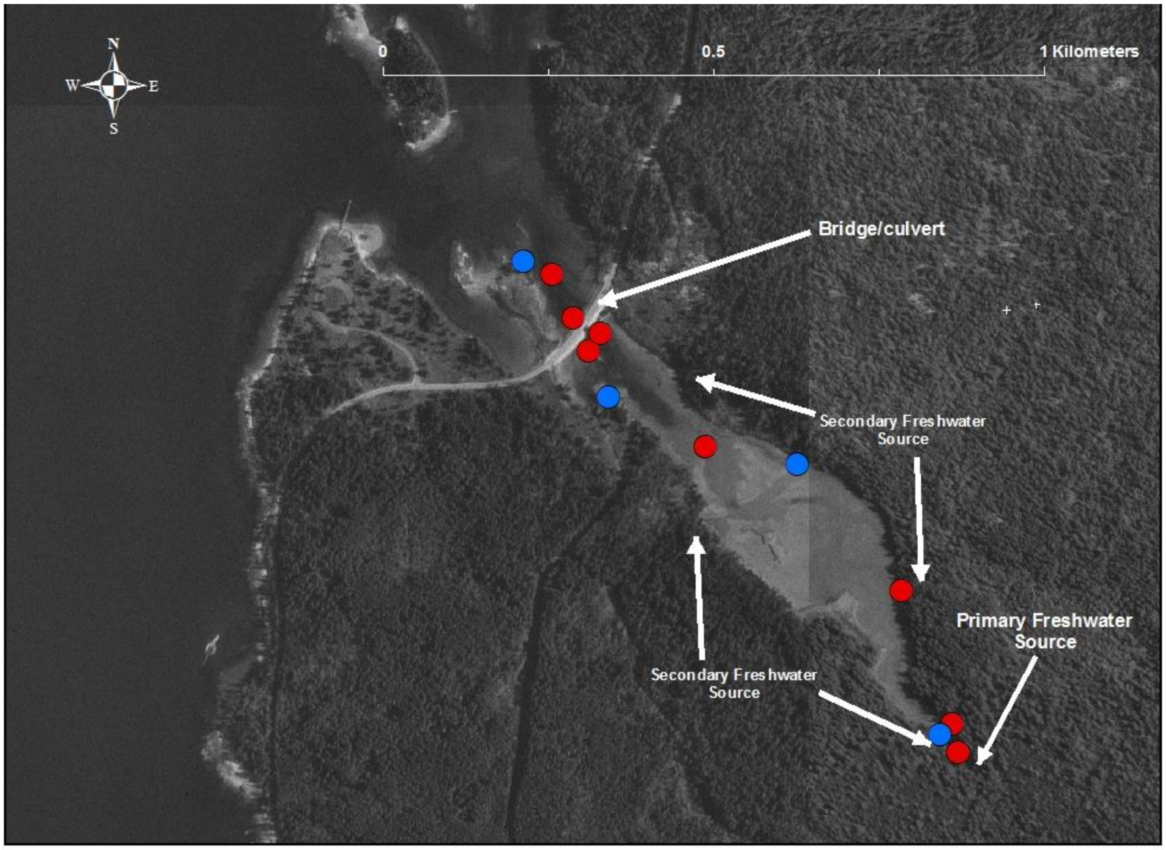

Figure 6.5. Location of 2002 traps (red circles) and 2003 seines (blue circles) relative to culvert and freshwater sources in the Mosquito Cove estuary. For location of Mosquito Cove estuary see Figure 2.1.

Chapter 7

ESTUARINE FISH IN ACADIA NATIONAL PARK: PATTERNS AND TRENDS

Adrian Jordaan and John Speirs

A. Introduction

The coastal zone covers a fraction of the Earth's area, yet it provides a disproportionate amount of primary and secondary productivity on which society and marine ecosystems depend. Humans have heavily settled coastal regions because of their plentiful resources and access to trade, and in 2003 approximately 53% of Americans live in 673 US coastal counties (Crossett et al. 2004). Most major cites were built on rivers or locations where rivers and ocean meet, known as estuaries. An estuary is a semi-enclosed coastal body of water with a free connection to the open sea and within which seawater is measurably diluted with freshwater derived from land drainage (Cameron and Pritchard 1963). Anthropogenic pressures tend to be exacerbated in estuaries, necessitating studies and inventories of the species present and the environmental constraints involved in shaping their distributions.

Acadia National Park manages a landmass of 152.32 km^2 in the downeast region of Maine, primarily on Mount Desert Island (MDI) but also including a portion of Schoodic Peninsula and Isle au Haut, 14 outer lying islands, and authorization by Congress (Boundary Map #123-80, 011; 1986) to acquire and manage conservation easements. The easement authority includes parcels and islands between lands adjacent to Schoodic Peninsula to the north and then southward to the Penobscot Shipping Channel. The Park's mission of conservation of lands within this area justifies the park's interest and involvement in research projects and long-term monitoring efforts.

Few studies have been performed on fish species in Acadia National Park embayments, which include estuaries, bays, coves and harbors, and their relative populations and fish sizes. Brackish water provides habitat for species of fish during different parts of their life cycles (Laprise and Dodson 1989). Intertidal species found in embayments are often necessarily euryhaline and the ability to occupy varying locations along the salinity gradient will influence their ultimate distribution (Laprise and Dodson 1989).

The goal of this chapter is to document the relationship between fish species and their environment and discuss the patterns and trends in the abundance and distribution of estuarine fish species. We will use inventories of fish captured in five high-salinity estuaries in Acadia National Park during 2002 and 2003 (Chapter 6; Appendix 5-24), to provide a better understanding of fish population dynamics in park estuaries. The data from 2002 is presented from two sampling periods, one from 06-14-2002 to 07-15-2002, and the second from 08-20-2002 through 09-14-2002.

B. Results

Mummichogs were dominant in both sample periods (Table 7.1 and 7.2), although the catch was reduced from 91% to 81% of the total catch, possibly by small changes in the gear types used such as the use of a seine in one location and the movement of one trap to a more brackish location. Northeast Creek, Bass Harbor and Somes Sound sites were associated with the largest mummichog populations in both sample periods, with Northeast Creek and Bass Harbor containing the higher total populations due to the much larger area they cover (see Figures 6.1 – 6.5).

The initial temperature, salinity, and sigma-t (density) values from CTD casts made in 2003 at each estuary mouth at high tide during a 9-day period (Tables 7.3, 7.4 and 7.5) show that Somes Sound sites had the warmest and lightest water. The bottom water is more telling of long-term conditions since it is the least affected by rainfall and solar heating while the high tide provides the source of deeper marine water that advances into the estuaries. Salinity values near 30‰ indicate some freshwater influence, but the temperatures and salinities at the bottom are typical summer coastal values. The following two months of data (Figure 7.1 -7.6) demonstrate changes in the systems with increasing temperatures and decreasing salinities. The Seal Cove and Mosquito Cove remained cool and salty compared to the warmer and fresher waters associated with the Northeast Creek, Bass Harbor and Somes Sound sites.

The surface water is influenced by present conditions (solar heating, rain), while the bottom water is more characteristic of processes within the estuaries themselves. Somes Sound sites are sheltered by Somes Sound and the result is reduced mixing and elevated water temperatures. The Bass Harbor estuary and sampling area was located at the head of Bass Harbor and begins near a culvert located just above the low tide mark. Bass Harbor CTD data during a flood tide demonstrated how water column mixing is influenced by the culvert (Figure 7.7). As the flood tide passes through the flow restriction at the culvert, the water column becomes mixed, and the salinity, temperature, and density become intermediate compared to the original surface and bottom values (Figure 7.1).

In all the study estuaries, once the mixed water enters the impoundment on the estuary side of the culvert, solar heating and evaporation begin to play an important role in determining temperature (Figure 7.8) and salinity. Ultimately, this mixed water returns to the marine environment at the low tide. The harbor outside of the Bass Harbor sampling sites is substantially smaller and shallower than the sound outside of the Somes Sound sampling sites. Seal Cove, and to a greater extent Mosquito Cove, are short and less protected compared to Bass Harbor and Somes Sound estuaries. This can be seen in the more marine signature in terms of temperature (colder; Table 7.3), salinity (saltier; Table 7.4), and density (heavier; Table 7.5). Northeast Creek was the most protected estuary, with extensive mudflats and a location on the leeward side of Mount Desert Island. The location and morphology of Northeast Creek and surrounding area were responsible for keeping the water temperature high (Table 7.3), and the more significant freshwater input was responsible for the lower salinity and density in the bottom sample, which affects the water being input into the estuary during flooding tides (Table 7.4, 7.5).

In both sampling periods during 2002, mummichogs were the dominant species captured by a wide margin, in particular in Northeast Creek and upper Bass Harbor (Table 7.1, 7.2). Bass Harbor was kept as two sampling units (upper and lower) to demonstrate the increasing numbers of mummichogs towards the freshwater end. The increase in mummichog abundance in the second sampling period (Table 7.2) was due to the addition of a trap and dipnetting along a branch of the marsh with limited freshwater input. Other relevant observations were that Mosquito Cove contained more solely marine species like lumpfish, cunners, short-horned sculpin and grubbies (Table 7.2). There was an increased capture of alewives, and silversides during the second sample period (Table 7.2) when a seine was used in sampling. Also in Bass Harbor a seine captured 43 black-spotted stickleback, not caught in any other estuary. Since only a few seines were completed and the bias of minnow traps is well documented (Layman and Smith 2001), 2002 data are used only to make cursory observations.

For each of the estuaries sampled during 2003, temperature and salinity at the surface and bottom of the water column generally showed warming and increasing salinity as the season progressed (Figures 7.9 – 7.13). This is presumably due to reduced freshwater input and evaporation in the marsh areas. The effect of the spring flooding on salinity can be seen in Figure 7.11, where the freshwater influence is clear at Northeast Creek sampling sites. Salinities are higher in the later part of the summer because of decreasing freshwater input.

The location of sampling within an estuary varied according to the amount of freshwater entering the system, the topography surrounding the estuary and the position of the culvert relative to the mean tide level (Figure 7.9-7.13). Seal Cove and Northeast Creek both had much longer distances between the mean low tide and culvert position (over 350 m) compared to the other estuaries (less than 250 m). Furthermore, the end of marine influence above the culvert varied between estuaries with Bass Harbor and Northeast Creek having the longest distances (~ 2000 m) compared to Seal Cove (less than 200 m) and Mosquito Cove and Somes Sound (~ 1000 m). The advance of ocean water was blocked by boundaries in Seal Cove, Somes Sound, Mosquito Cove (sharp rise in topography) and Bass Harbor (beaver dam). Northeast Creek contained no boundary to flow, but the location of the culvert so high in the estuary only permitted spring tides to spill into the impoundment. The presence of the impoundment also allowed the salinity at the bottom to remain high, except in the earliest sample period (Figure 7.6).

The fish sampling from 2003 (Figure 7.9-7.13) shows that the distribution of the estuarine mummichog (*Fundulus heteroclitus*) and fourspine stickleback (*Apeltes quadracus*) differed in relation to the physical landmarks within the estuary (culverts, mean low tide mark, etc.). Fish were absent from the marine stations in Seal Cove, where estuarine conditions were limited to within 200 m above the culvert. For Seal Cove, Somes Sound and Mosquito Cove the stations closest to freshwater were generally the most consistently brackish and contained estuarine species. Exceptions to this existed in Northeast Creek where ninespine sticklebacks (*Pungitius pungitius occidentalis*) and banded killifish (*Fundulus diaphanous,* not shown) were caught, and Bass Harbor where ninespine sticklebacks and Golden Shiners (*Notemigonus Crysoleucas* – not shown) were caught in larger numbers at the freshwater site. Bass Harbor and Northeast Creek had vast brackish water areas inhabited by the estuarine species. Atlantic silversides (*Menidia menidia*) young-of-year were often found with mummichogs at freshwater sites, particularly late in the year.

Table 7.1. Numbers of individuals caught during the first sampling period in 2002, pooling all gear types. Mosquito Cove was not sampled during the first sampling period.

Species	Seal Cove	Somes Sound	Bass Harbor	Northeast Creek	Species Total
Mummichog	289	638	499	1941	3367
3-Spine stickleback	1	19	48	9	77
4-Spine stickleback	23	0	21	10	54
9-Spine stickleback	0	20	28	2	50
American eel	2	16	3	22	43
Atlantic silverside	0	0	3	2	5
Rock gunnel	0	2	0	0	2
Sea catfish	1	0	0	0	1
Cunner	1	0	0	0	1
Estuary Total	317	695	602	1986	3600

Table 7.2. Numbers of individuals caught during the second sampling period in 2002, pooling all gear types.

Species	Seal Cove	Somes Sound	Bass Harbor	Northeast Creek	Mosquito Cove	Species Total
Mummichog	613	1132	1511	1350	122	4728
3-Spine stickleback	0	1	279	0	0	280
4-Spine stickleback	59	0	92	22	0	173
9-Spine stickleback	0	0	18	66	0	84
American eel	1	0	4	14	2	21
Atlantic silverside	3	712	280	23	29	1047
Lumpfish	0	0	0	0	34	34
Atlantic Mackerel	1	0	0	0	3	4
Alewife	61	1	41	1	0	104
Banned killifish	0	0	0	1	0	1
Cunner	0	0	0	0	6	6
Black-spotted stickleback	0	0	43	0	0	43
Short-horn sculpin	0	0	0	0	1	1
Grubby	0	0	0	0	1	1
Estuary Total	738	1846	2268	1477	198	6527

Sand shrimp (*Crangon septemspinosa*) were more abundant in the June sampling period and declined to low abundance during the August sampling period, and appeared to retreat from the freshwater sites (Appendix 27). Adult blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoharengus*), Atlantic herring (*Clupea harengus*) and sandlance (*Ammodytes americanus*) were all encountered somewhat randomly and were not included in the figures but are included in the original data appendices (5-24). Notably, herring were found in Seal Cove and Mosquito Cove and sandlance in Mosquito Cove. In contrast, river herring (alewife, blueback) were caught in Bass Harbor, Northeast Creek, and Somes Sound sites.

Our results indicated a decrease in size for mummichogs and silversides as young recruiting fish were captured by seines later in the season (Figure 7.14). Other observations include the absence of blackspotted stickleback during August, and the slight increases in size of sand shrimp and ninespine sticklebacks, with the other species showing little change (Figure 7.13).

C. Discussion

A large part of changes in fish abundance is related to the seasonal cycle, in particular the reproductive cycle and growth of young fish (Lazzari et al. 1999, Collette and Klein-MacPhee 2002). All the species recorded in this study, except mummichogs, move into the estuaries after over-wintering in the marine environment. Species become susceptible to sampling gear as a function of their body size and timing of entrance into the estuaries. Young fish are not caught in the seine until they achieve some minimum size (~1 cm), or until the temperature and other physical characteristics of the water matches the requirements for migration into the embayments.

The data for two species (mummichogs and silversides) show clear recruitment of young fish. Mummichogs spend their entire lives in the estuaries, and are the only year-round resident species. They appear to leave estuaries to overwinter in pools on marsh surfaces (Smith and Able 1994) or bury themselves in the mud during the winter and reemerge in the spring when conditions permit (Chidester 1916). American eel also burrow in soft mud within estuaries or rivers (Collette and Klein-MacPhee 2002). The fate of the remaining freshwater fish within the estuaries remains unknown. They are a shallow water species that is euryhaline and, as a result, they occupy an array of marsh habitats from salt marshes, where they are especially abundant, to eel grass beds, open shores and many altered and impacted habitats where few other species can survive (Collette and Klein-MacPhee 2002). Mummichogs are extremely abundant in the brackish water portions of the estuary early in summer. They reproduce in early spring or summer and the newly hatched eggs recruit as juveniles later in the summer. Their location high in the estuaries may be to avoid predation, to take advantage of available food resources, or to coincide with conditions of ideal temperature and salinity, or, more probable, some combination of these factors.

As the 2003 summer progressed, the lack of freshwater input and higher temperatures may have altered the distribution of many species. There was a movement of mummichogs into upper regions of the estuaries as the recruitment of juvenile fish increased. The smaller fish prefer a less open habitat in more constricted areas, so smaller fish were encountered closer to the sources of freshwater. Marine species could be seen in greater numbers towards the end of the summer when colder, more saline waters prevailed.

Silversides spawn in the estuaries and young-of-year are often found with mummichogs at freshwater sites, particularly late in the year. Silversides move into estuaries during the summer to spawn. Sampling found them throughout the estuaries as adults and young juveniles. Silversides lay adhesive eggs that are associated with marsh grasses (*Spartina* spp.). They became more abundant in the month of August when young were large enough to be sampled. Even-sized individuals, who could be conjectured to come from the same year-class, dominate schools of silversides. They can be caught along mud/sand/gravel shoreline, in particular within marsh grasses (*Spartina* spp.), and are never far from shore. *Spartina* spp. are common within inner bays and in river mouths. As a result, silversides are common in brackish water and are generally restricted in distribution to shallower than two meters, except in winter when they leave the estuary to avoid low temperature. Spawning occurs in June and July in the Gulf of Maine, and eggs are deposited on sandy bottoms and on *Spartina* spp. up to the high tide mark (Collette and Klein-MacPhee 2002).

Migratory saltwater forage fish can dominate samplings due to their schooling behavior. Blueback herring and alewives, both anadromous species, use the estuaries for feeding and must pass through them to migrate to the ocean as young and to spawn in freshwater as adults (Collette and Klein-MacPhee 2002). These two fish of the family Clupeidae have historically been and continue to be of importance to the commercial fishing industry, and are captured in herring fisheries around MDI (A. Jordaan, Personal Observation).

Most marine sticklebacks are restricted to the shoreline, and many spend their full lives in estuaries. However, in the harsh northeastern United States winter, all sticklebacks leave the estuaries. The threespine stickleback is small (less than 9 cm) and can occupy full freshwater and full seawater. They are caught occasionally in the open ocean, often in association with floating seaweeds (Collette and Klein-MacPhee 2002). Threespine sticklebacks enter creeks and estuaries in the spring to spawn, usually in schools (A. Jordaan, Personal Observation), and are associated with deeper water during the winter (Collette and Klein-MacPhee 2002). Their diet includes copepods, isopods, schizopod shrimp, young squid, young fish and eggs; some are known to feed only on diatoms (Collette and Klein-MacPhee 2002).

The range of the ninespine stickleback is much the same as the threespine, and this species also spawns in summer along the shore. It is chiefly restricted to harbors and the creeks in salt marshes, where large numbers can be caught with mummichogs (A. Jordaan, Personal Observation; Collette and Klein-MacPhee 2002). Fourspine sticklebacks are common in salt marshes, as are other sticklebacks and mummichogs. They are primarily restricted to salt and brackish conditions, although other life history and diet characteristics are similar to the threespine stickleback (Collette and Klein-MacPhee 2002). When sampling occurred in more freshwater conditions, the ninespine stickleback, banded killifish, golden shiner, and other species began to replace the mummichog as the most abundant species.

The scale of the estuary area in the present study is small compared to more conventional estuarine systems. Bass Harbor Marsh, Northeast Creek and Seal Cove all had measurable freshwater flow throughout the summer. Somes Sounds and Mosquito Cove had substantial flow in the month of June, but freshwater supply decreased significantly over the summer and the only significant flow was after periods of rainfall (A. Jordaan, Personal Observation); therefore, the freshwater input had little effect on the salinity within the full embayment. These two smaller bays might not be considered estuaries by some more accustomed to larger, more complex estuaries and merely considered embayments. However, a measurable dilution of salt water and the presence of estuarine fish species support the classification of the Somes Sound and Mosquito Cove sites as estuaries. Still, many of the estuaries were dependent on rainfall for the freshwater component of their flow. May and June of 2003 were associated with plentiful rain and cooler temperatures. Tidal flow was more effective later in the summer and saltwater advanced further up into the estuary because of decreased freshwater input.

Bass Harbor is a shallow estuary, and it constantly receives freshwater through the summer, though freshwater inundation decreases as the watershed becomes dryer due to lack of rain. The station closest to freshwater had low salinity values at the surface and bottom, and was located just below a beaver dam. The golden shiner, a freshwater species, was captured there, although its presence may have been due to being flushed over the dam rather than choice. In Northeast Creek, golden shiners were captured, as well as banded killifish, which appeared to share some habitat with its close relative the mummichog. Without a barrier to movement, such as the dam in Bass Harbor, the fish appeared to venture into estuarine conditions by choice. Fish collected in Northeast Creek were generally located in the lower sampling stations, closer to the salt water, and were mainly saltwater species that are physiologically challenged by freshwater.

The presence of culverts affected all the estuaries, although the location relative to mean tide level was different in each of them. The primary effect was due to constricted channels at the site of the culvert, where there was high water flow and potential productivity (see Leonard et al. 1998). In particular, the gradient in temperature and salinity could be nullified by turbulent mixing upstream (flood tide) or downstream (ebbing tide) from culverts. The influence of culverts in Acadia National Park estuaries cannot be overlooked. They are present in all the estuaries, and due to varying placement and local topography, they have different influences on dynamics within the estuaries. Seal Cove and Northeast Creek have bridge/culverts that are high relative to mean tide level. Seal Cove has a sharp increase in topography towards Seal Cove Pond, which limits the build up of water on the freshwater side of the culvert. As the summer progressed, mummichogs and silversides utilized this area, although in reduced numbers compared to other estuaries. On the saltwater side of the culvert in Seal Cove there were few species, and mummichog and silverside numbers were drastically reduced. At Northeast Creek, the relief on the freshwater side of the culvert was dominated by a large marsh with little to no rise in topography. The result is a large pool of brackish water, which from the 2002 sampling was found to contain large numbers of mummichogs. During low tide, the brackish pool of water drains over the mudflat and fringing marsh below the culvert. The increased freshwater input compared to Seal Cove enabled the use of the area by large numbers of mummichogs and silversides, as well as sticklebacks.

The situation in Bass Harbor, Somes Sound and Mosquito Cove is different in that the culverts are found lower in the system, trapping a pool of saline water before the freshwater influences the salinity. We did not have any sampling stations on the marine side of the culvert at Somes Sound for logistical reasons, but the marine stations at Bass Harbor and Mosquito Cove did not produce many individuals or species of fish, except for a large school of blackspotted sticklebacks during the second sample at Bass Harbor. Bass Harbor shares topography similar to Northeast Creek, with a large low salt marsh extending away from the culvert in the freshwater direction. Mummichogs and silversides were again common, but other species were capable of movement into the area due to a stronger saltwater input. All three low-culvert sites had the most anadromous species captured; however, it is not possible to give any estimate of the population health or the effect of obstructions to flow on survival and growth. The placement of the culvert relative to the tidal range and the natural topography of the estuary interact to influence the spatial organization of estuarine conditions and, as a result, the distribution of species.

Table 7.3. Temperature (°C) on the surface and bottom of water column based on CTD casts at the mouth of each estuary in 2003.

	Bass Harbor	Seal Cove	Northeast Creek	Somes Sound	Mosquito Cove
Date	06/10	06/14	06/12	06/19	06/13
Surface	12.6	8.5	12.2	15.0	9.7
Bottom	9.2	8.3	12.1	13.6	7.5
Depth (m)	4	5	2	1.5	3

Table 7.4. Salinity (‰) on the surface and bottom of water column based on CTD casts at the mouth of each estuary in 2003.

	Bass Harbor	Seal Cove	Northeast Creek	Somes Sound	Mosquito Cove
Date	06/10	06/14	06/12	06/19	06/13
Surface	30.6	31.0	30.6	27.3	32.0
Bottom	32.1	31.6	30.9	31.6	32.8
Depth (m)	4	5	2	1.5	3

Table 7.5. Sigma-t on the surface and bottom of water column based on CTD casts at the mouth of each estuary in 2003.

	Bass Harbor	Seal Cove	Northeast Creek	Somes Sound	Mosquito Cove
Date	06/10	06/14	06/12	06/19	06/13
Surface	23.1	24.1	23.1	20.1	24.6
Bottom	24.8	24.5	23.4	23.6	25.6
Depth (m)	4	5	2	1.5	3

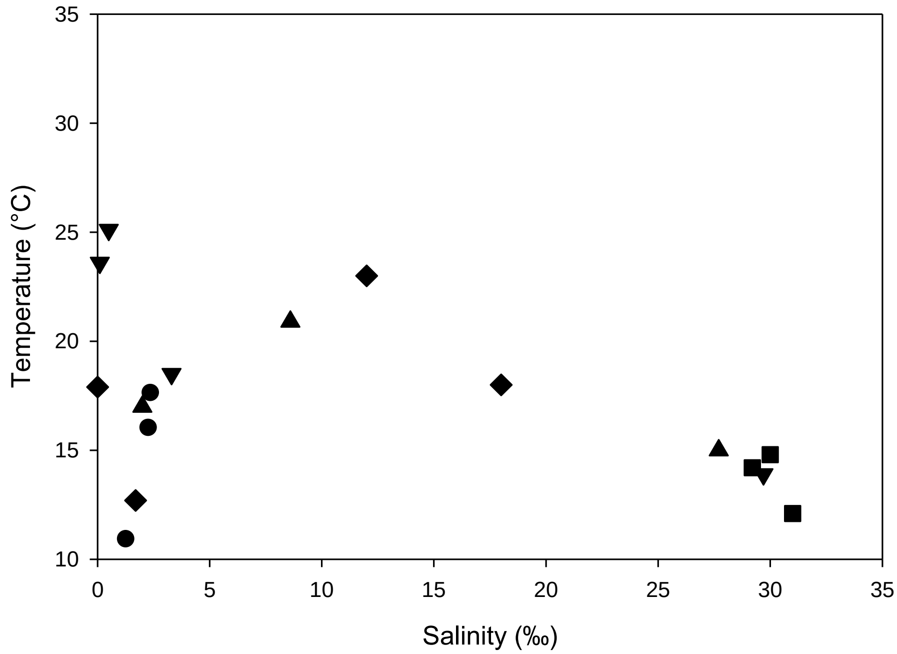

Figure 7.1. Surface temperatures-salinity diagram for Seal Cove (circles), Northeast Creek (inverted triangle), Somes Sound (triangle), Bass Harbor (diamond) and Mosquito Cove (square) during the first round of sampling in June, 2003.

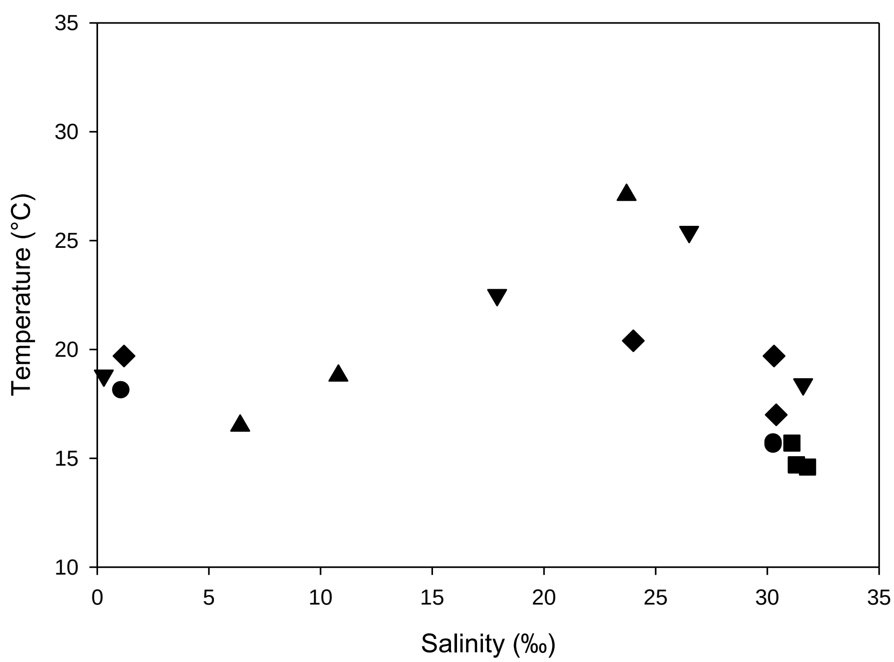

Figure 7.2. Surface temperatures-salinity diagram for Seal Cove (circles), Northeast Creek (inverted triangle), Somes Sound (triangle), Bass Harbor (diamond) and Mosquito Cove (square) during the first round of sampling in July, 2003.

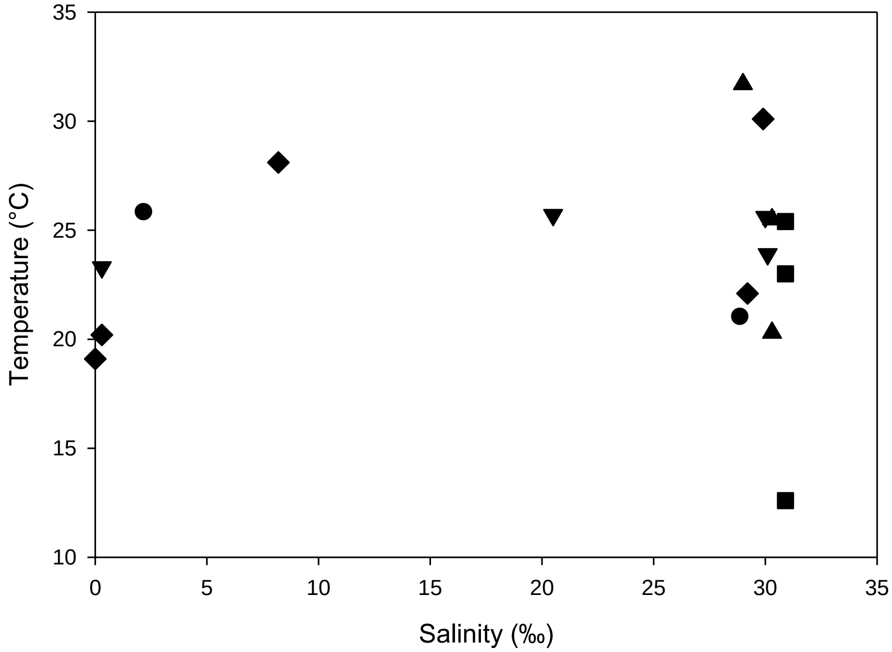

Figure 7.3. Surface temperatures-salinity diagram for Seal Cove (circles), Northeast Creek (inverted triangle), Somes Sound (triangle), Bass Harbor (diamond) and Mosquito Cove (square) during the first round of sampling in August, 2003.

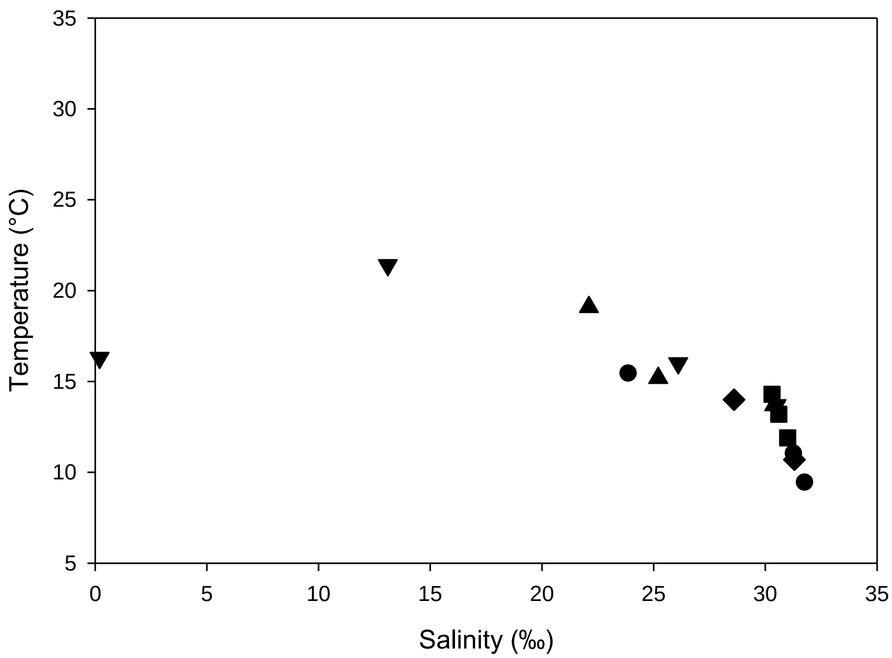

Figure 7.4. Bottom temperatures-salinity diagram for Seal Cove (circles), Northeast Creek (inverted triangle), Somes Sound (triangle), Bass Harbor (diamond) and Mosquito Cove (square) during the first round of sampling in June, 2003.

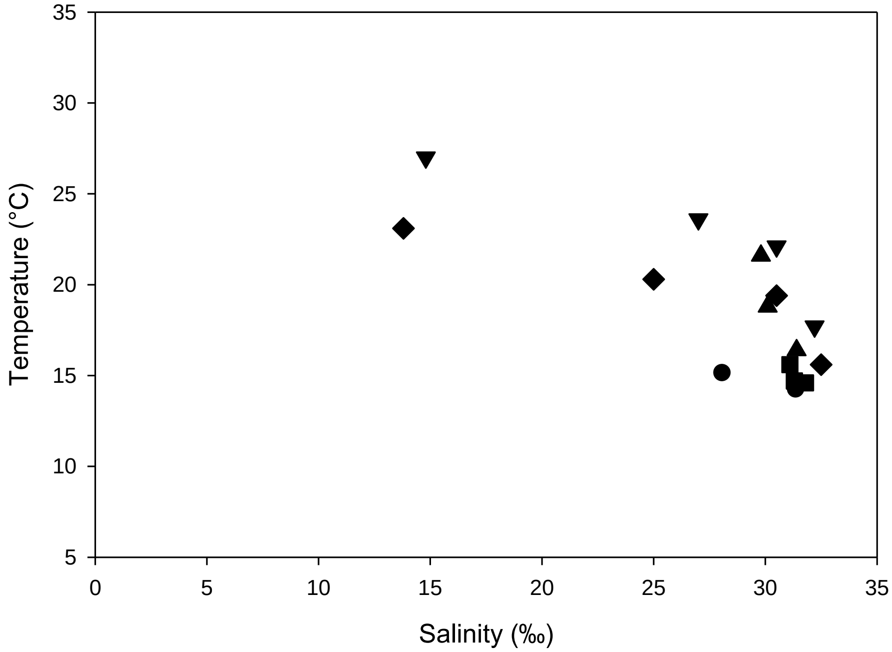

Figure 7.5. Bottom temperatures-salinity diagram for Seal Cove (circles), Northeast Creek (inverted triangle), Somes Sound (triangle), Bass Harbor (diamond) and Mosquito Cove (square) during the first round of sampling in July, 2003.

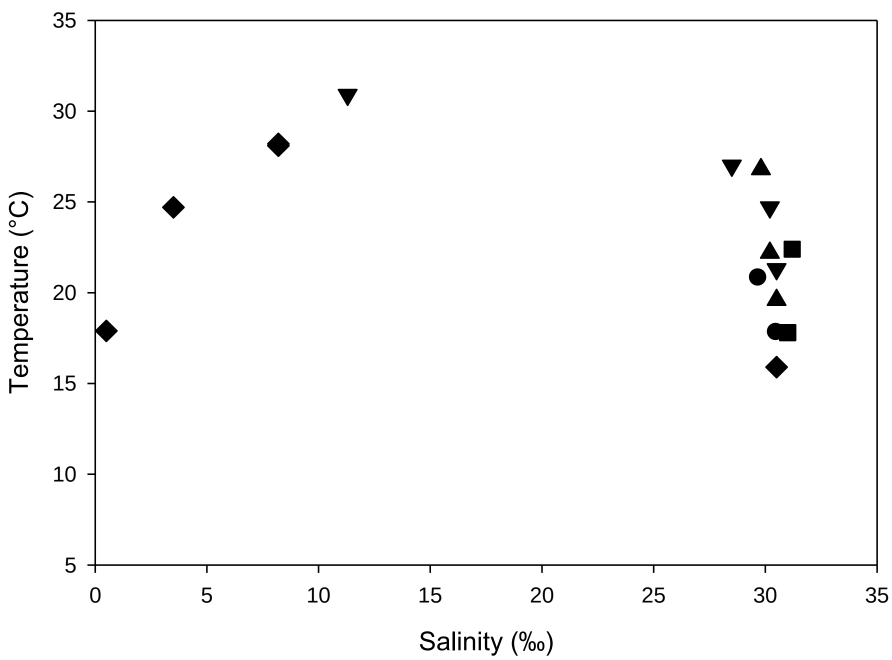

Figure 7.6. Bottom temperatures-salinity diagram for Seal Cove (circles), Northeast Creek (inverted triangle), Somes Sound (triangle), Bass Harbor (diamond) and Mosquito Cove (square) during the first round of sampling in August, 2003.

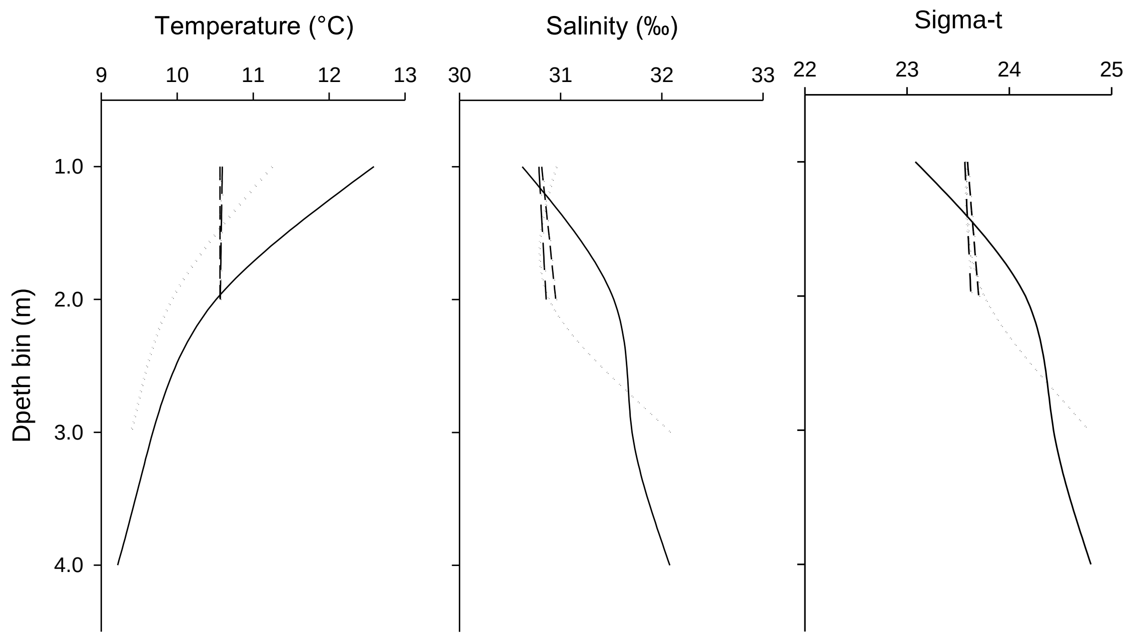

Figure 7.7. Temperature, salinity and sigma-t values from Bass Harbor collected by CTD on 06/10/2003. Station 1 (solid line) and 2 (dotted line) were located on the ocean side of a culvert, and station 3 and 5 were on the marsh side (dashed lines). Mixing of water occurs at the culvert, and the depth is reduced quickly as one moves up the estuary towards freshwater.

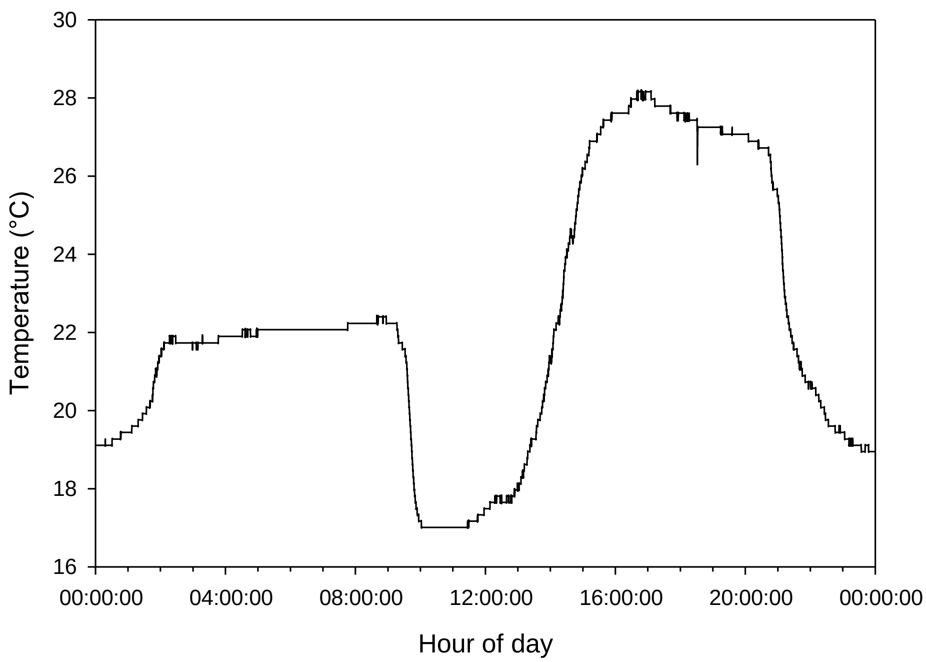

Figure 7.8. Temperature profile from logger placed in Northeast Creek on 07/09/2002. Note the cooler period during midday, when colder ocean water contacts the logger. The temperature during the afternoon ebbing tide (between 16:00 and 20:00 hrs) increased 6°C due to solar heating, compared to the nighttime ebbing tide (between 04:00 and 08:00 hrs). High tide was at approximately 10:00 hrs.

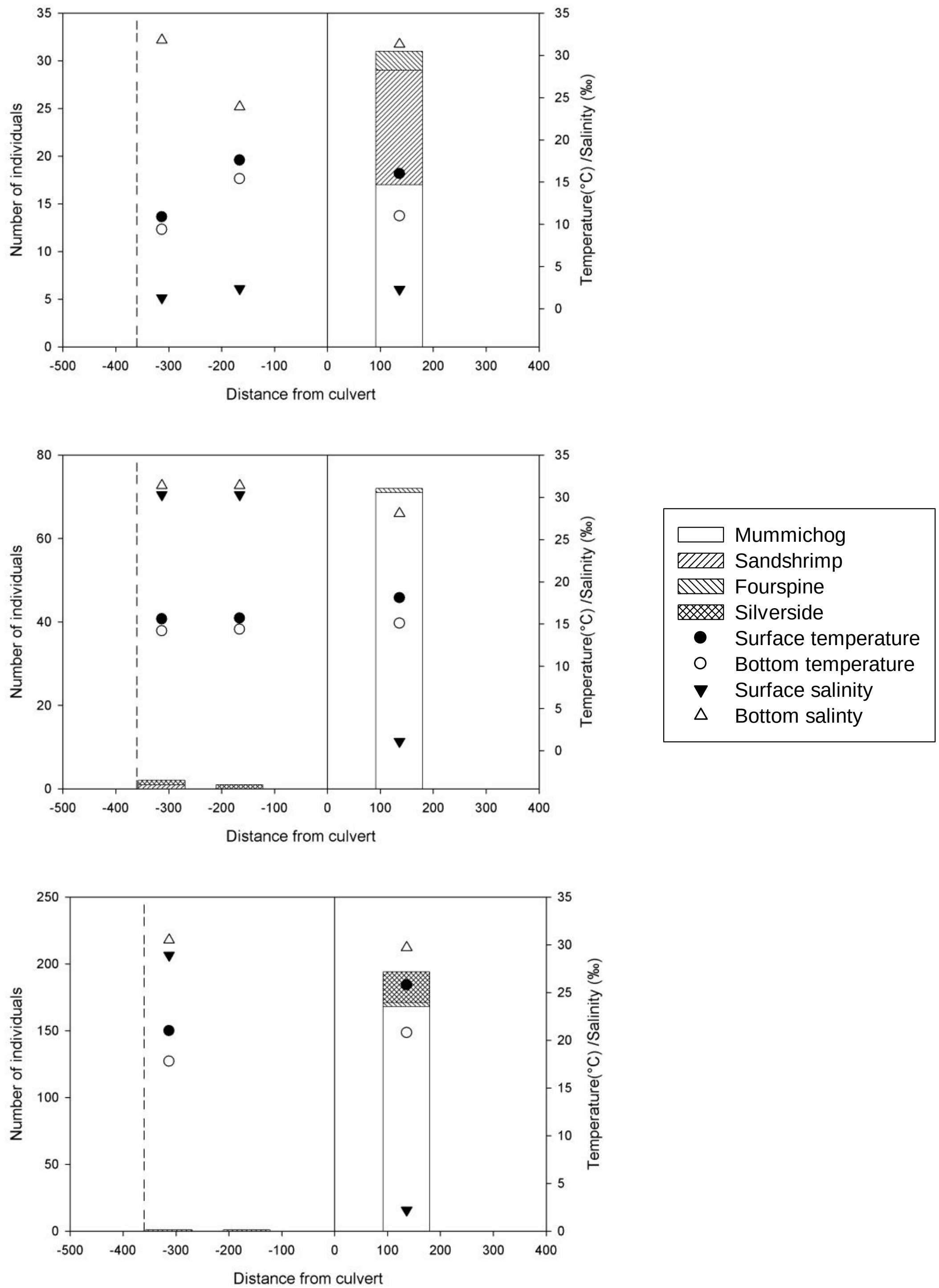

Figure 7.9. Fish species, temperature and salinity encountered during sampling at Seal Cove in 2003. Dates are 6/16/2003 (top), 7/15/2003 (middle) and 8/17/2003 (bottom). The solid line indicates position of culvert in estuary, and dashed line indicates the low tide mark. The most freshwater site effectively represents the boundary of freshwater influence.

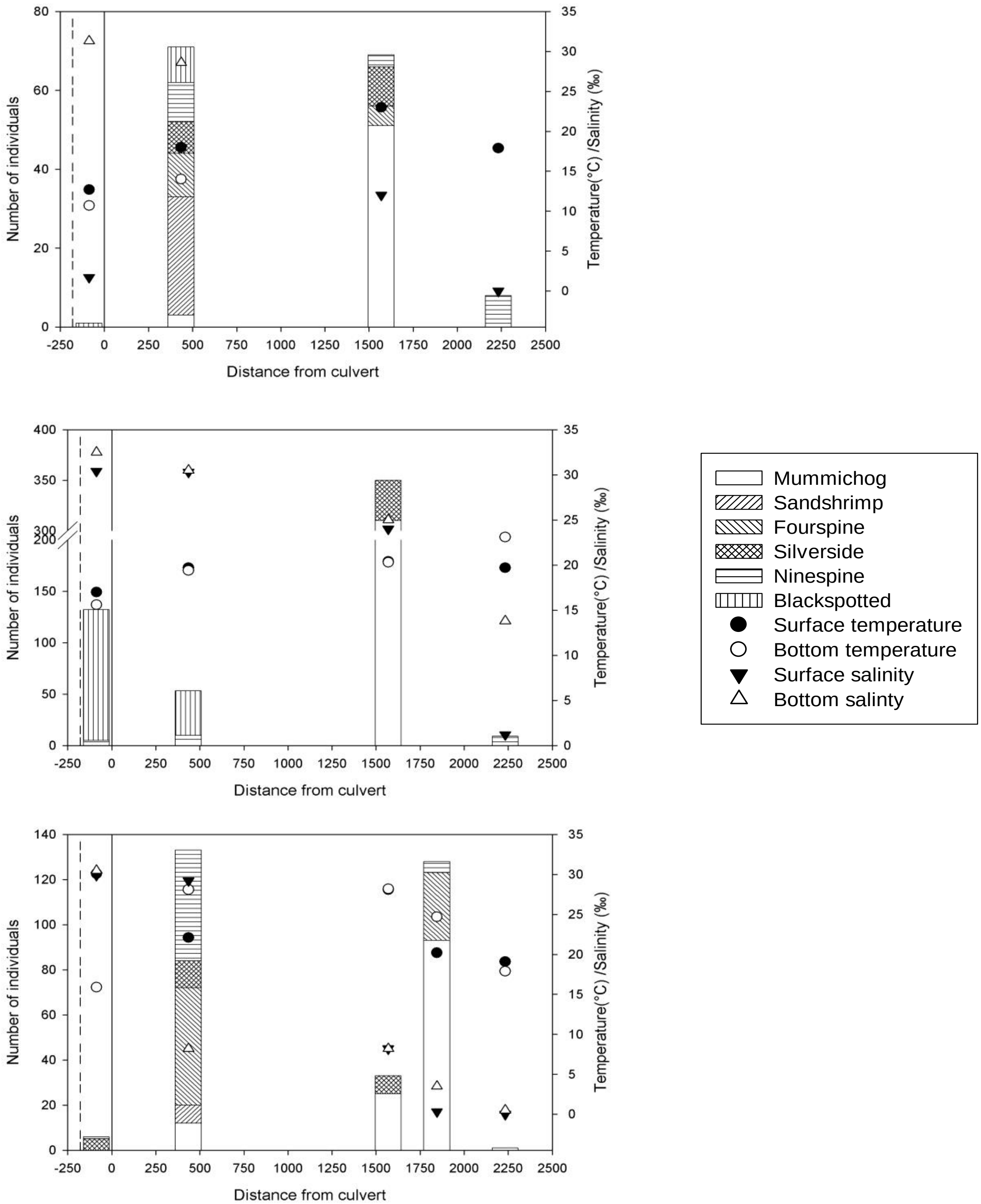

Figure 7.10. Fish species, temperature and salinity encountered during sampling at Bass Harbor in 2003. Dates are 6/21/2003- 6/22/2003 (top), 7/21/2003 (middle) and 8/17/2003 (bottom). The solid line indicates position of culvert in estuary, and dashed line indicates the low tide mark. The most freshwater site effectively represents the boundary of freshwater influence.

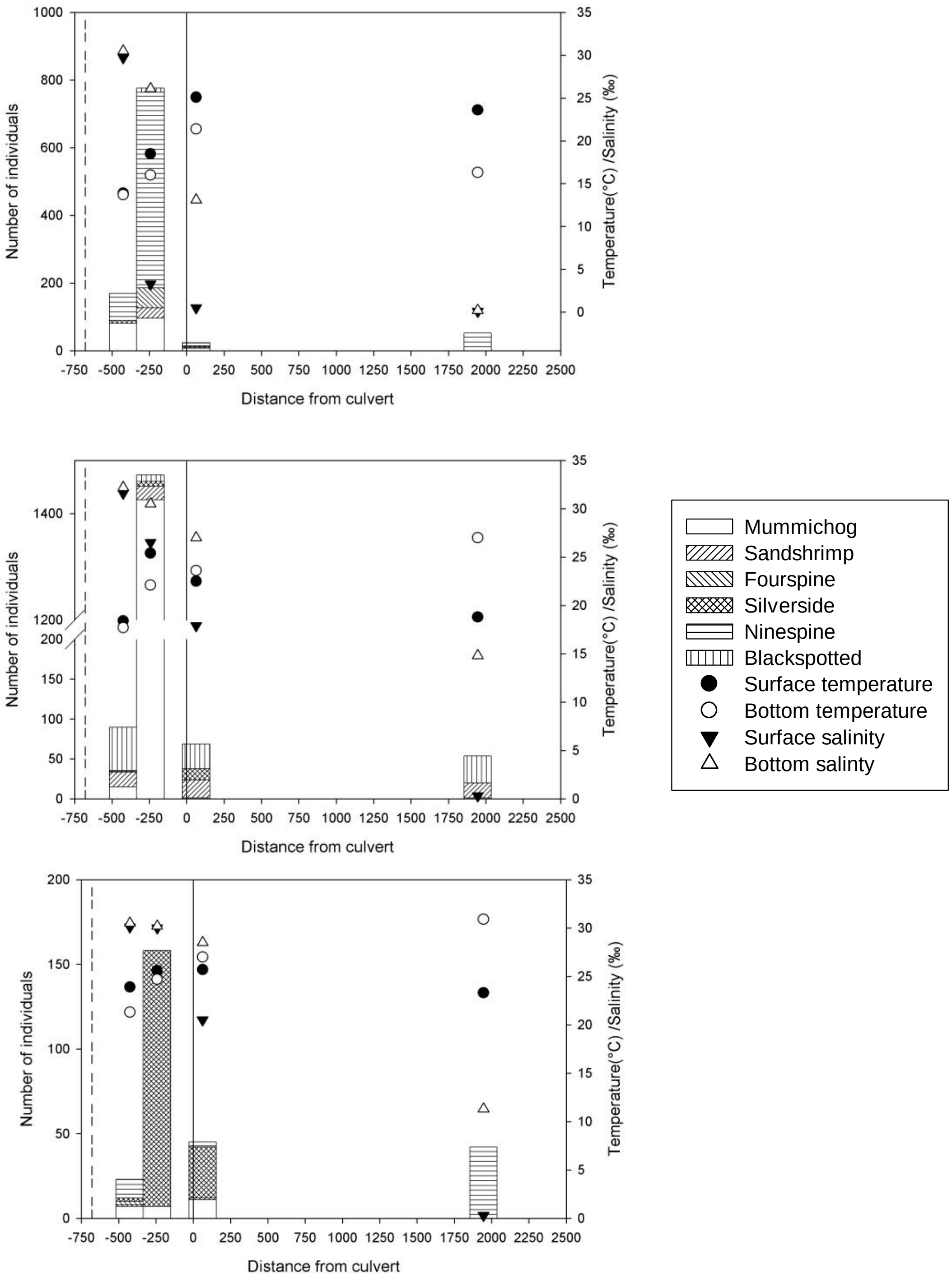

Figure 7.11. Fish species, temperature and salinity encountered during sampling at Northeast Creek in 2003. Dates are 6/24/2003 (top), 7/18/2003 (middle) and 8/19/2003 (bottom). The solid line indicates position of culvert in estuary, and dashed line indicates the low tide mark. The most freshwater site effectively represents the boundary of freshwater influence.

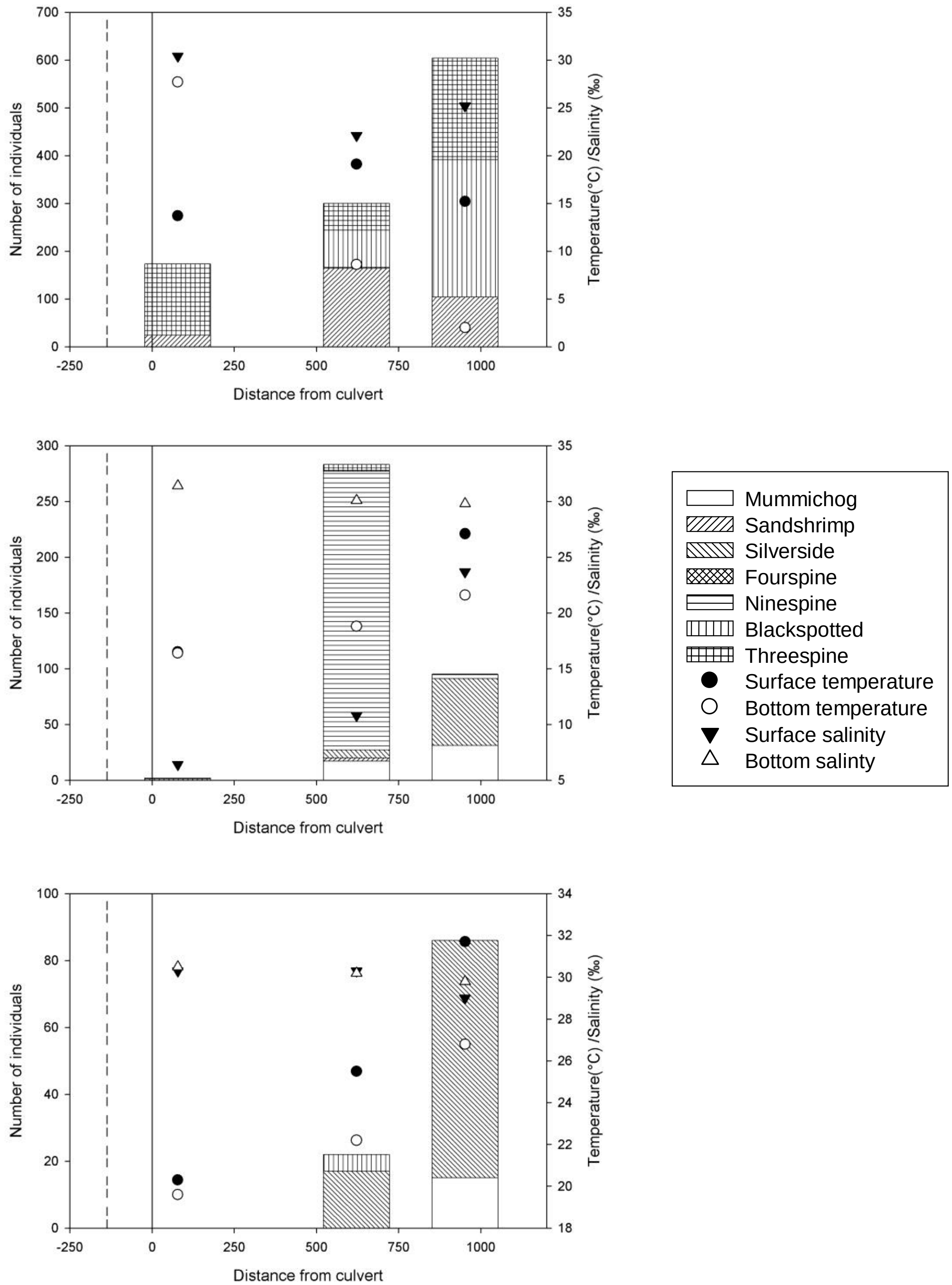

Figure 7.12. Fish species, temperature and salinity encountered during sampling at Somes Sound in 2003. Dates are 6/19/2003(top), 7/17/2003 (middle) and 8/16/2003 (bottom). The solid line indicates position of culvert in estuary, and dashed line indicates the low tide mark. The most freshwater site effectively represents the boundary of freshwater influence.

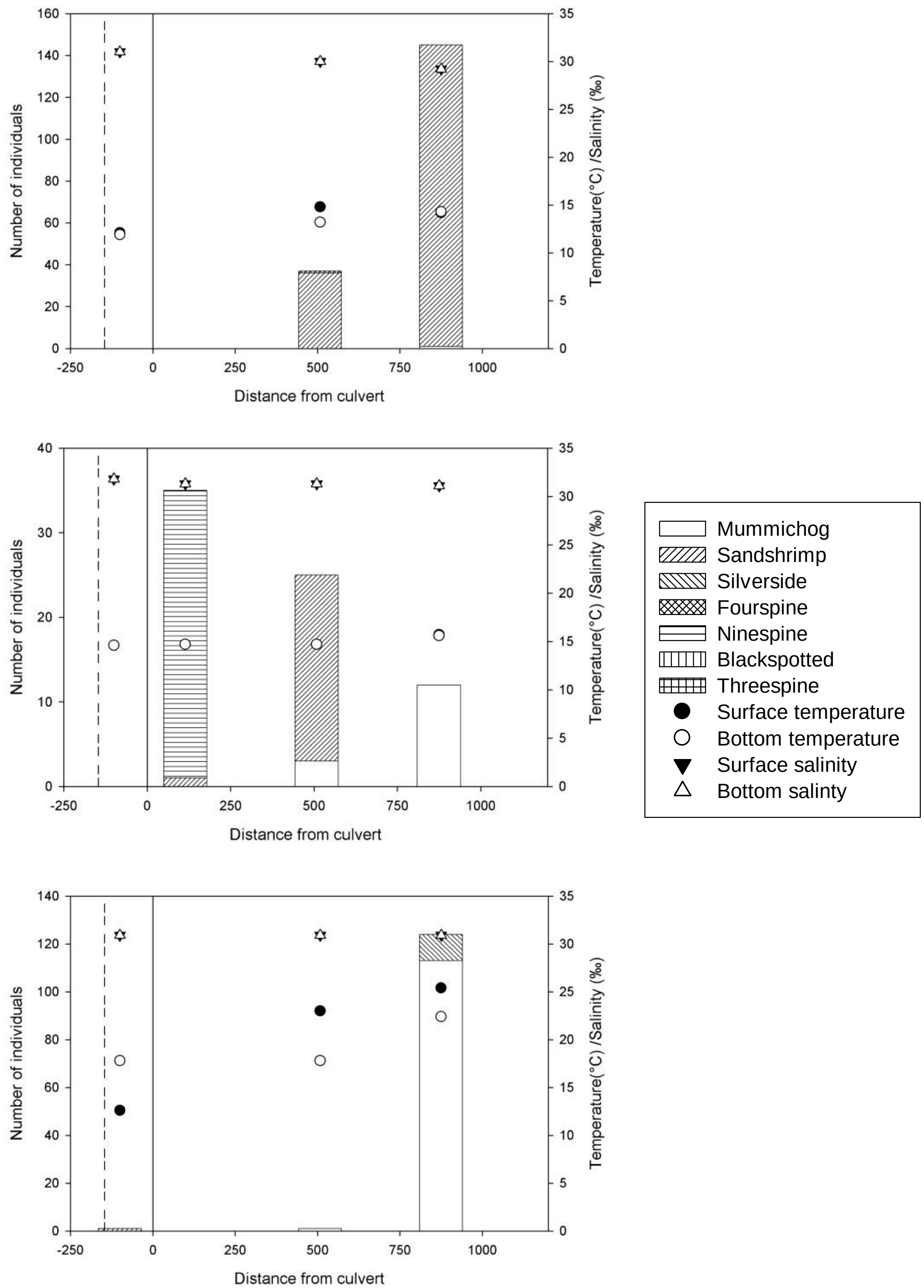

Figure 7.13. Fish species, temperature and salinity encountered during sampling at Mosquito Cove in 2003. Dates are 6/25/2003 (top), 7/22/2003 (middle) and 8/20/2003 (bottom). The solid line indicates position of culvert in estuary, and dashed line indicates the low tide mark. The most freshwater site effectively represents the boundary of freshwater influence

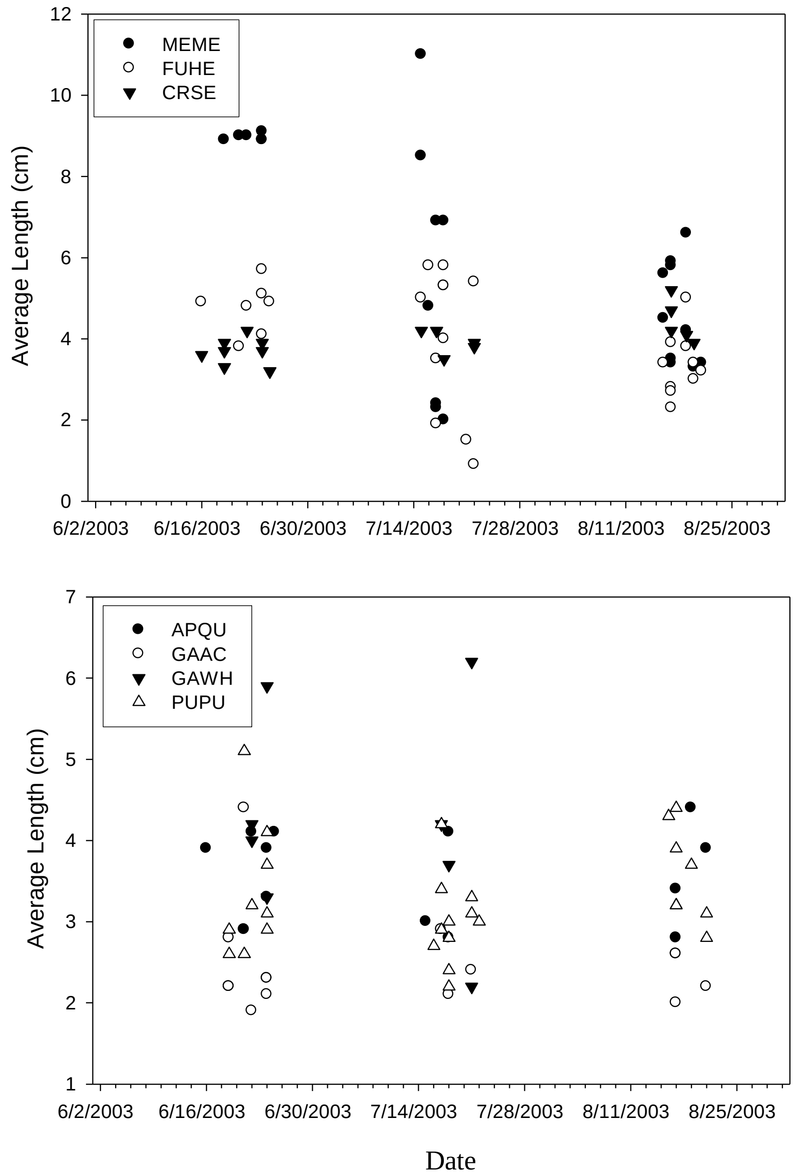

Figure 7.14. Average lengths of mummichogs (FUHE), silversides (MEME), sandshrimp (CRSE) (top), and fourspine (APQU), threespine (GAAC), blackspotted (GAWH) and ninespine (PUPU) sticklebacks (bottom) at each sampling location.

Chapter 8

IMPLICATIONS OF INTERTIDAL INVENTORY AND ANALYSIS FOR MANAGEMENT IN ACADIA NATIONAL PARK

Adrian Jordaan

A. Major Conclusions

Patterns of tidepool fish may be best described by the geomorphology of the area, and the resulting sediment composition and algal communities. These patterns are embedded in the seasonal trend of fish abundance, as different species move in and out of the intertidal zone. We are encouraged to report an abundance of marine life inhabiting tidepools across Acadia National Park. Future intertidal work should examine the effect of wave exposure of the study sites, which may be correlated to many of the other important variables, and which may affect fish assemblages.

The estuaries of Acadia National Park are like most in the New England region. Road construction and over-exploitation of anadromous fish populations have altered the structure of the systems. It is not possible to give many recommendations without more complete studies of the interactions among these impacts. Managers will need to understand species/community changes and modifications in the flow regime of estuaries to be able to make informed decisions. It would be worth knowing whether estuarine fish communities could be described on the basis of the presence, absence, or position of culverts in relation to the natural topography.

It is clear that with the impending expansion of human population throughout the Acadia region (Figure 8.1), watershed land-use changes and shoreline construction will produce obstructions within estuaries and will alter patterns of erosion and sedimentation that need to be monitored. Dramatic changes have already occurred, and without appropriate management actions the loss of biodiversity could be further compounded over the coming decades.

B. Linking humans to ecological conditions

Recent research has shown that a hierarchical series of filters influence the abundance, presence, and absence of species (Magnuson et al. 1998; Poff 1997). These filters help to determine which "species traits" are compatible with a given ecosystem (see Figure 8.2). Three broad categories of ecosystem drivers can be identified: abiotic, biotic, and human. Abiotic drivers are parallel with human drivers because in these systems the two are controlling the biotic drivers. Humans have influenced the environment through the building of dams, bridges, and culverts which have changed flow patterns and modified habitat. Heavy fishing pressure, eutrophication, introduction of invasive species, and stocking of non-native anadromous fish populations have fundamentally altered ecosystem function. Abiotic factors such as “natural” or background climate change, currents, tides, latitudinal gradients and geologic setting also influence biotic conditions. Further complicating the designation of positions in a hierarchy is the link between the different scales, and cycles that may be nested within complex systems.

At a most basic level, estuaries are the mixing of two systems (freshwater and marine) with their respective species. The gradient in human, abiotic and biotic drivers from the marine and freshwater end-members will influence overall estuarine processes. Of note is that freshwater human drivers have been more significant than human drivers from the marine end member, but the interaction of the two has had far reaching effects. The loss of anadromous fish due to freshwater habitat destruction and marine fisheries is the primary example. It is estimated that the historic populations in the St. Croix River of 7000 – 18,000 salmon and 31,700,000 alewives have been reduced to populations presently less than 1% those values (Lotze and Milewski 2004).

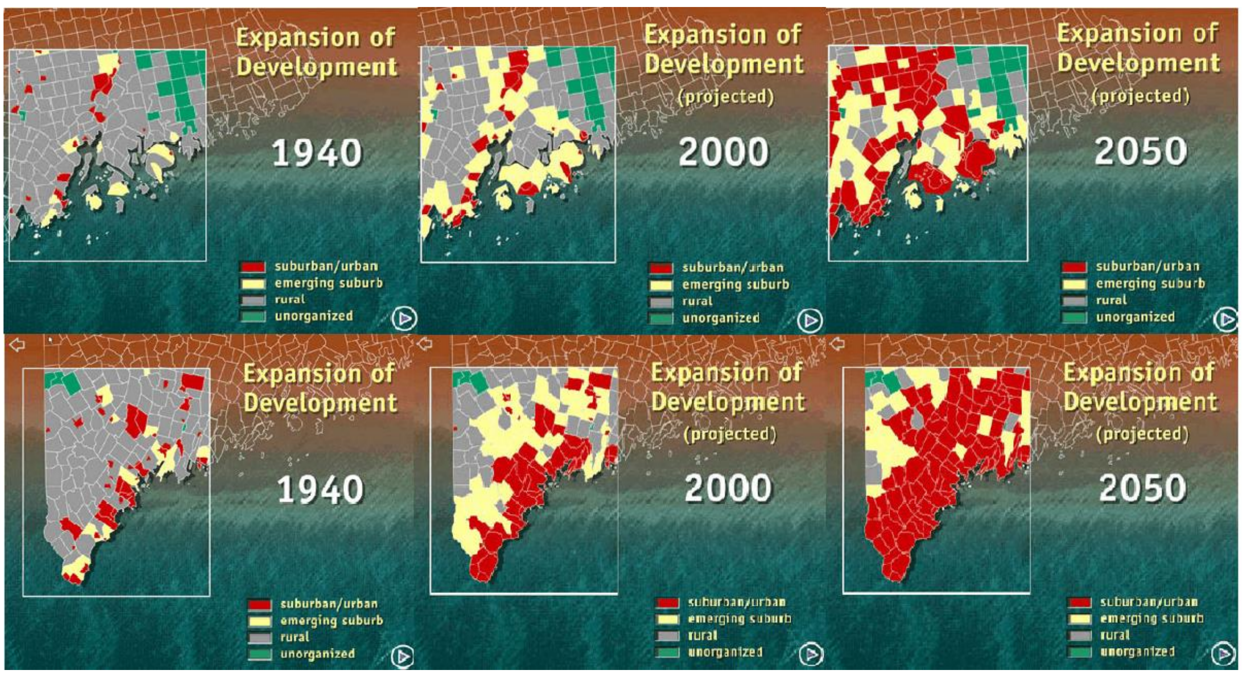

Figure 8.1. Land use since 1940 and projected to 2050 for the vicinity of Acadia National Park (top panel) and southern Maine (bottom panel). Figure from Maine State Planning Office (see: http://www.state.me.us/spo/landuse/techassist/expansion/state.php).

Listing the drivers that are important in structuring an ecosystem is an important first step in establishing management strategies. Without understanding these drivers, a management plan may focus on processes that are not on the appropriate temporal or spatial scales for successful realization of goals (see Gunderson and Holling 2002).

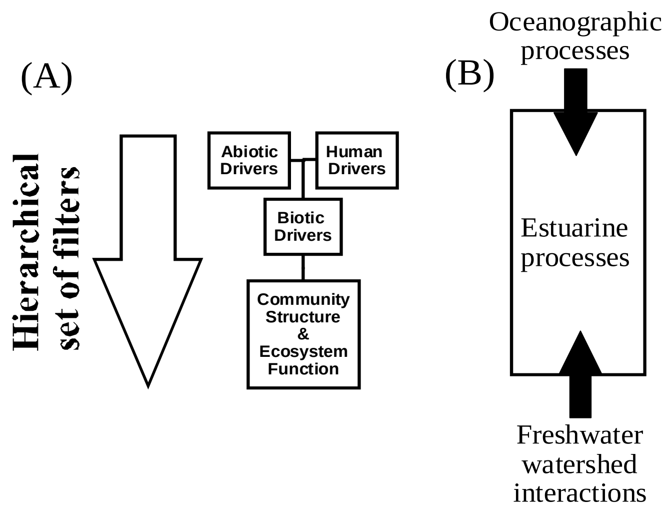

Figure 8.2. Hypothesized drivers for a typical Maine estuary from a broad scale perspective (see text for discussion)

1. Abiotic Drivers

Estuaries are dynamic systems where tidal influences on the delivery of marine source water interact with seasonal and long-term patterns in the freshwater flow regime. The landscape of estuaries has a major effect on patterns of water flow and the spatial arrangements of flora and fauna (Chen et al. 1999). Composition of the local community is initially influenced through the extent of isolation from source habitats and the rates of local extinctions and immigrations (Magnuson et al. 1998). The landscape also directly affects the duration and intensity of solar radiation and the reception, retention and movement of water. This is important because variation in microclimate over temporal and spatial scales also influences community structure, particularly through influences on patch dynamics (Chen et al. 1999).

In freshwater, nitrogen and phosphorus concentrations have been shown to limit production and anthropogenic inputs of these elements are related to eutrophication and deterioration of water quality in streams (Carpenter et al. 1998). The water residence time in watersheds, as well as land-use differences among watersheds and the underlying geology, will determine the relative concentrations of biologically important elements.

Seasonal trends and less predictable storm events both play roles in the amount of rainfall discharge that flows through the watersheds and enters into estuarine systems (National Climatic Data Center/ NESDIS/ NOAA; Doering et al. 1995).

In Acadia National Park estuaries, the marine input of nutrients tends to dominate over freshwater input, except when nitrogen loading occurs in the freshwater source (Doering et al. 1995). The Gulf of Maine is among the world's most biologically productive marine environments and experiences a strong tidal cycle. The primary source of marine nutrients in the Gulf of Maine is deep (>200m depth) Slope Water (SLW), which enters the gulf through the Northeast Channel. The nutrient-rich SLW is brought into the euphotic zone by: (1) tidal mixing and upwelling, (2) fluxes across the seasonally established pycnocline, and (3) winter convection (Townsend 1991). An upwelling zone in the eastern Gulf of Maine supplies cool nutrient-rich water to the Eastern Maine Coastal Current, which flows just offshore from the study area, and may occasionally move inshore (Xue et al. 1999). The phytoplankton community structure and ratio of nitrogen to phosphorous change over time as increasing light and high nutrient concentrations due to winter convection lead to large phytoplankton blooms in the spring (Townsend 1998). These temporal effects influence the relative contributions of each water source into estuarine ecosystems.

2. Biotic drivers

Typical North American aquatic biotic drivers are salmon (*Oncorhynchus* spp. - 5 Pacific coast species; *Salmo salar* - Atlantic salmon) and beaver (*Castor canadensis*). Anadromous fish return to freshwater to spawn and then die, bringing marine nutrients to inland freshwater ecosystems. Both gametes and carcasses provide food for animals and nutrients for plant growth and bacterial production (Gende et al. 2002). Salmon on the west coast can leave up to 5.4×10^{7} kg of biomass per watershed in the form of nutrients and macroelements (Gende et al. 2002). Beaver are viewed as "ecological engineers" (Schlosser and Kallemeyn 2000) because their dam-building activities (Naiman et al. 1988) result in significant influences on ecosystem structure. Dam-building by beaver results in "patch bodies" where water is impounded. Beaver activities result in reduced flow, retention of sediment and nutrients in the channel, presence of wetlands, modifications to the riparian zone, and changes in the character of water and materials transported downstream. These alterations result in a significant influence on the composition and diversity of plant and animal communities (Naiman et al. 1988; Schlosser and Kallemeyn 2000). The influence of differences in life histories, such as longevity and iteroparity (in contrast to semelparous for Pacific salmon) of the river herring and other clupeid fish, should be considered since they will have an impact on nutrient cycling and productivity of the systems

The estuaries in ANP receive spawning fish from the marine environment in the form of Atlantic silversides (*Menidia menidia*) and clupeids (Chapter 7) and have beaver and river otter (*Lutra canadensis*) activity in some watersheds (Dubuc et al. 1991). Otters utilize beaver lodges as winter refuge sites, and feed extensively in the estuarine and marine environments during the winter months (Dubuc et al. 1991). A substantial number of terrestrial and avian species and oceanic predators have also been observed or sampled at the study sites (Doering et al. 1995; A. Jordaan, Personal Observation). Sea-run brook trout have also been described in the Bass Harbor estuary by local recreational fishermen, but none were encountered in sampling. However, sampling techniques were not extensive enough, or designed to, target sea-run trout, and more research will be necessary to confirm their presence and document their ecological importance. A quantification of biota, and food-web interactions through use of stable isotope analysis, will be important in determining biotic factors that drive community structure across habitats.

The primary biotic driver in Acadia's estuarine systems is likely the spatial arrangement of vegetative cover. It has been shown that increased vegetative cover, which in northeastern estuaries is primarily eelgrass (*Zostera marina*), widgeon grass (*Ruppia maritima*) and cordgrasses (*Spartina* spp.), is an important contributor to invertebrate and fish community structure (Roman et al. 2000). Bruno and Bertness (2001) review how marine foundation species can modify the habitat. Corals, kelp, mussels, salt marsh grasses, and seagrasses all modify the physical environment. These species have "facilitator traits" which alter the physical conditions and provide structure for other species. The most important facilitator traits are: habitat creation (refuge for other species), reduction in flow and the accumulation of sediment (salt marshes), reduction in physical and physiological stresses, enhancement of propagule supply/retention, and increased food supply (see Table 8.2, Bruno and Bertness 2001).

3. Human Drivers

The consideration of human drivers of ecosystem dynamics is important because altering human activities may be the most feasible form of management. Human activities can modify the physical parameters of an ecosystem by altering structural features (Chen et al. 1999). Other major anthropogenic drivers are: increased nutrient-loading into freshwater systems, altered precipitation patterns, freshwater diversion for other uses, and land-use (Cloern 2001; Fry 2002). Mobilization of nitrogen and phosphorous caused by land clearing, fertilizer use, sewage, and animal production is of serious consequence to environmental health (Cloern 2001). Urbanization increases the concentrations and fluxes of nutrients through stream ecosystems (Carpenter et al. 1998) and into estuaries (Roman et al. 2000). Alterations in growth and fecundity of estuarine populations due to urban and agricultural non-point source run-off have previously been reported (Porter et al. 1997). Coastal eutrophication is a recently defined problem, but it produces significant changes in the biogeochemical and ecological functioning of ecosystems (Cloern 2001).

In Acadia National Park the most significant landform change in the estuarine systems is the construction of bridges (Chapter 7). Bridge building results in the same type of effects seen with beaver dams, and produces substantial salt marsh habitats. The large brackish water reservoirs form an expansive environment for mummichogs (*Fundulus heteroclitus*), perhaps to the exclusion of more desired species like salmonids. The placement of bridges relative to the mean tide level (the average sea level) is different across the estuaries, resulting in very different patterns in water mixing and other physical and biological parameters (Chapter 7). Physical and biological processes interact in a complex and non-linear fashion (Figure 8.2; Chen et al. 1999), necessitating well-planned research that employs multiple techniques such as field studies combined with laboratory trials and modeling.

Bridge construction is a necessary infrastructure component along the highly indented Maine coastline. However, the culverts, and the consequent impoundment of brackish water, help to create habitats that favor euryhaline/thermal species. This may be to the detriment of other species or result in a barrier to anadromous fish migration. The impoundment of water can be significant in area and volume, as in Northeast Creek and Bass Harbor, and the production of mummichog and stickleback species is astonishing. Northeast Creek, in particular, demonstrated a dense and ubiquitous distribution of mummichogs. The loss of many anadromous species from these watersheds was an expressed concern of multiple landowners in the region during the course of this study. The impact of culvert position on the diversity of fish in estuaries, and whether changes in the design and construction of culvert systems can restore the natural flow regime, could offer simple and affordable management options. Not recognizing the interaction amongst different components of ecosystems (freshwater anadromous species, marine predators, human infrastructure, and fishing pressure) has been a major failing in management plans to date.

C. Improving management

The coastline is a seamless entity with fuzzy boundaries. Estuaries have been separated from rocky intertidal shores in research and management because there are fundamental differences in patterns and process between the two. There are dramatic differences in the fish, invertebrate and algal assemblages between the quiet areas of sediment accumulation and the exposed areas of shoreline erosion. For this reason, it appears to be important to describe where and how habitats are created in relation to physical and geomorphic processes. The intertidal zone may generally be classified as: (1) rocky sediment-poor habitat or (2) mudflat/salt-marsh sediment-rich habitat. Exposed shorelines are expected to be rocky intertidal areas, whereas those in protected margins, at the head of embayments, or in other areas where currents are minimized and substantial sedimentation occurs are expected to be mud flat and salt marsh habitat. Coastal development and sea-level change both influence whether areas will be exposed coastline or a local quiet area. Developing quantitative techniques that can differentiate between the two habitat types, along a gradient of wave energy, will allow a better understanding of the distribution of mudflat and rocky coast under different scenarios of coastal change. That change could be natural such as sea level or due to coastal constructions.

The influence of culverts on sediments, salt-marsh health and the distribution of species should receive attention. Are all of the marshes on MDI the result of man-made impoundments, or do some pre-date this type of anthropogenic disturbance? Management actions directed at culverts are relatively simple and could have significant impacts of the condition of estuaries.

Other important data deficiencies are a lack of understanding of: (1) how changes to physical and physiological demands by habitat modification effects different fish species, (2) over-wintering capabilities of sticklebacks within the estuarine habitat, (3) potential impacts of river herring to nutrient budgets of freshwater systems, and (3) the upstream spawning habitat of anadromous fishes, and how to maintain continuity between the ocean and that habitat. These are but a few of many questions that need additional study.

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Appendix 1. Common and scientific names with abbreviation of the species observed in this inventory.

Algae and Grasses

Common Name	Scientific Name	Abbreviation
Eelgrass	*Zostera marina*	ZM
Cordgrasses	*Spartina* spp.	SS
Knotted wrack	*Ascophyllum nodosum*	AN
Rockweed	*Fucus vesiculosus*	FV
Brown filamentous algae	*Desmarestia aculeata, Scytosiphon simplicissimus, Petalonia fascia*	BF
Brown "fuzzy" alga	*Ectocarpus fasciculatus*	EF
Irish moss	*Chondrus crispus*	CC
Sugar kelp	*Laminaria saccharina*	LS
Horsetail kelp	*Laminaria digitata*	LD
Edible kelp	*Alaria esculenta*	AE
Maidenhair	*Enteromorpha*	EN
Sea lettuce	*Ulva lactuca*	UL
Green algae	*Chaetomorpha,* *Spongomorpha,* *Urospora penicilliformis*	CH SP URPE
Purple laver	*Porphyra umbilicalis*	PU
Dulse	*Rhodymenia palmate*	RP
Crustose algae	*Hildenbrandia prototypus, Corallina officinalis* (crusting form)	CA
Coral weed	*Corallina officinalis* (Branching form)	CD

Invertebrates

Common Name	Scientific Name	Abbreviation
Barnacle	*Semibalanus balanoides* *Balanus amphitrite*	SB
Mussel	*Mytilus edulis*	ME
Periwinkle - common	*Littorina littorea*	LL
Periwinkle - smooth	*Littorina obtusata*	LO
Periwinkle - rough	*Littorina saxatilis*	LS
Common whelks	*Buccinum undatu* *Nucella lapillus*	BC
Limpet	*Tectura testudinalis*	AT
Sponge	*Microciona prolifera*	MP
Crabs	*Cancer irroratus,* *Carcinus maenas*	CR
Hermit Crab	*Pagarus longicarpus*	PL
Sea Star	*Asterias forbesi*	AF
Brittle Star	*Ophiopholis aculeate*	OA
Sea urchin	*Strongylocentrotus droebachiensis*	SD
Amphipod	*Gammarus spp.*	GS
Isopods	*Spheroma spp,* *Idotea spp* *Erichsonella spp.*	IS
Nudibranch	Order: Nudibranchia	NU
Scaleworm	Family: Polynoidae	PO
Worms	*Tetrastemma vermiculum* and other nematodes	TV
Anemone	*Urticina feline* *Metridium senile*	AN
Sea cucumber	*Cucumaria frondosa*	CF
Egg Donuts		ED
Egg Droplets		EP
Egg Ropes		ER
Shrimp	*Palaemonetes* spp.	PS

Fishes

Common Name	Scientific Name	Abbreviation
Blueback herring	*Alosa aestivalis*	ALAE
Alewife	*Alosa pseudoharengus*	ALPS
Inshore sandlance	*Ammodytes americanus*	AMAM
American eel	*Anguilla rostrata*	ANRO
Fourspine stickleback	*Apeltes quadracus*	APQU
Herring	*Clupea harengus*	CLHA
Lumpfish	*Cyclopterus lumpus*	CYLU
Mummichog	*Fundulus heteroclitus*	FUHE
Banned killifish	*Fundulus diaphanous*	FUDI
Threespine stickleback	*Gasterosteus aculeatus*	GAAC
Blackspotted stickleback	*Gasterosteus wheatlandi*	GAWH
Sea raven	*Hemitripterus americanus*	HEAM
Pumpkinseed	*Lepomis gibbosus*	LEGI
Atlantic snailfish	*Liparis atlanticus*	LIAT
Atlantic silverside	*Menidia mendia*	MEME
Grubby	*Myoxocephalus aenaeus*	MYAE
Longhorn sculpin	*Myoxocephalus octodesemspinosus*	MYOC
Short-horned sculpin	*Myoxocephalus scorpius*	MYSC
Golden shiner	*Notemigonus crysoleucas*	NOCR
Rainbow smelt	*Osmerus mordax*	OSMO
Rock gunnel	*Pholis gunnellus*	PHGU
Pollock	*Pollachius virens*	POVI
Winter flounder	*Pseudopleuronectes americanus*	PSAM
Ninespine stickleback	*Pungitius pungitius*	PUPU
Atlantic mackerel	*Scomber scombrus*	SCSC
Northern pipefish	*Syngnathus fuscus*	SYFU
Cunner	*Tautogolabrus adspersus*	TAAD

Birds

Common Name	Scientific Name	Abbreviation
Mallard	*Anas platyrhynchos*	ANPL
Osprey	*Pandion haliaetus*	PAHA
Great blue heron	*Ardea herodias*	ARHE
Belted kingfisher	*Megaceryle alcyon*	MEAL
Double-crested cormorant	*Phalacrocorax auritus*	PHAU
Bald eagle	*Haliaeetus leucocephalus*	HALE
American crow	*Corvus brachyrhynchos*	COBR
Pileated woodpecker	*Dryocopus pileatus*	DRPI
Sandpipers	*Scolopacidae spp.*	SCSP

Appendix 2. Summary of fish inventory of tidepools in Acadia National Park. Entries represent number of fish caught/average fish length in centimeters of all or a sampling of the fish caught. Numbers in italics are estimates when the population was too great to count. NM= not measured. TH=tide height. Tide height was the low tide value for the sampling period, in meters above or below mean low tide level. For location and description of pools see Table 3.1. Abbreviation identification is located in Appendix 1.

	TH	Pool	Temp	Salinity	POVI	FUHE	GAAC	APQU	MYOC	MYSC	MYAE	HEAM	PHGU	CYLU	LIAT	PLAM	FRY
	m	**ID**	**C**	**ppt**	**#**	**#**	**#**	**#**	**#**	**#**	**#**	**#**	**#**	**#**	**#**	**#**	**#**
Anemone																	
Cave																	
6/7/01	1	AC01	12	21													
		AC02	12	20													
		AC03	11	20													
		AC04	18	9													
		AC06	15	19													
		AC07	16	21													
		AC08	15	19													
7/7/01	0	AC01	10	12													
		AC02	11	12													
		AC03	13	13													
		AC04	11	13													
		AC06	15	14													
		AC07	15	14													
		AC08	17	14													
8/9/01	1	AC01	13	18													
		AC02	12	17													
		AC03	13	18													
		AC04	16	20						1/3.5							
		AC06	23	24													
		AC07	21	24													
		AC08	22	30													
9/27/01	2	AC01	12	22													
		AC02	13	26													
		AC03	13	19													
		AC04	14	24													
		AC06	17	22													
		AC07	16	22													
		AC08	16	22													
total fish										1							

Bass																	
Head																	
6/23/01	-0.1	BH01	11	23													
		BH02	11	23													
		BH03	11	24									2/4.0	2/0.7			
8/4/01	1.0	BH01	13	12													
		BH02	12	13									2/8.3				
		BH03	13	14						1/6.8			9/11.3	5/1.7			
9/15/01	-0.1	BH01	16	28													
		BH02	13	27									5/6.0		1/6.4		
10/17/01	-3.1	BH01	11	31													
		BH02	12	30									4/7.9		5/5.0		
		BH03	11	31						1/8.9			1/6.1		2/7.0		
total fish										2			23	7	8		
Bass Head																	
Lghthouse																	
6/8/01	1.3	BL01	10	23													
		BL02	10	25									12/12.7		1/8.7		
7/3/01	1.0	BL01	12	19													
		BL02	11	22									8/12.5				
8/5/01	0.2	BL01	13	13													
		BL02	12	15									7/13.0				
9/18/01	-1.7	BL01	13	26													
		BL02	12	24									10/12.6				
total fish													37		1		
Dorr Pt																	
6/8/01	-0.3	DP01	11	21	26/4.9						3/3.1		2/8.3				
7/6/01	-0.1	DP01	10	16	6/5.7							1/4.9	3/11.5	28/1.1	3/1.9		
7/31/01	1.3	DP01	15	17	1/8.0					3/4.8			5/9.0	20/1.3	1/3.2		
9/17/01	-1.5	DP01	14	26					2/6.4	1/6.3			5/6.8	3/2.1	2/5.0		
total fish					33				2	4	3	1	15	51	6		

Gorham																	
Mountain																	
6/24/01	-1	GM01	11	23													
		GM02	12	23						2/2.9			2/8.3	3/1.0	1/10		
7/23/01	-2	GM01	10	14						6/4.0			1/NM				
		GM02	11	15						1/3.7							
8/18/01	-1	GM01	12	30						4/4.6	1/5.8				2/2.7		
		GM02	13	32													
10/8/01	2	GM01	12	21							2/6.5				2/5.6		
		GM02	12	24													
total fish										13	3		3	3	5		
Little																	
Hunters																	
Beach																	
6/23/01	-1	LH01	12	24											1/1.4		
		LH02	12	25									2/9.5				
7/24/01	-2	LH01	11	14													
		LH02	13	15									1/9.9				
8/21/01	-1	LH01	13	25					9/6.5				1/12.0		1/3.2		
		LH02	13	24						1/4.9			1/10.4				
9/30/01	1	LH02	17	30													
total fish									9	1			5		2		
Moose																	
Island																	
6/19/01	1	MI01	12	30													
		MI02	15	29			1/2.9			1/6.9							
7/19/01	1	MI01	14	13													
		MI02	12	12			2/6.8										
8/21/01	-2	MI01	12	24													
		MI02	12	24			1/6.5										
10/21/01	1	MI02	10	32						1/9.4							
total fish							4			2							

Seawall																	
North																	
7/6/01	1.2	NN01	13	15													
		NN02	13	15													
7/30/01	1.2	NN01	16	16													
		NN02	16	20									1/13.0				
8/22/01	-1.5	NN01	15	26													
		NN02	13	24									1/6.0				
9/18/01	-1.6	NN01	14	26													
		NN02	15	27													
total fish													2				
Seawall																	
South																	
6/7/01	0.6	NS01	9	19	12/4.9									1/6.9			
		NS02	10	21									1/6.0	2/3.5	2/2.9		
7/23/01	-0.6	NS01	10	21						5/7.9			1/3.4	11/1.2	2/1.5		
		NS02	12	17						1/3.9			1/7.0	5/1.2	1/1.4		
8/22/01	-1.5	NS01	13	23						5/8.3			9/9.2	5/2.6	5/4.1		
		NS02	13	25									1/4.6	15/2.3	7/1.8		
9/18/01	-1.6	NS01	14	28						1/17.1	3/7.4				2/4.8		
		NS02	13	29									2/6.2		1/5.5		
total fish					12					12	3		15	39	20		
Otter Pt																	
6/9/01	0.0	OP01	10	21													
		OP02	10	21									3/13.9		4/7.8		
		OP03	11	22													
7/18/01	0.9	OP01	11	14							2/4.2			2/1.5			
7/7/01	1.3	OP02	10	14									2/14.4				
		OP03	10	13													
8/7/01	0.4	OP01	12	15						2/6.1			1/11.9				
		OP02	13	20									2/10.9		1/2.2		
		OP03	12	23						5/5.3							
9/29/01	1.3	OP01	14	23						6/6.6							
		OP02	13	21						2/6.5			2/11.0		9/6.3		
		OP03	14	21						3/6.0			1/6.3	1/3.0	1/6.5		103
total fish										18	2		11	3	15		

Pond																	
Island																	
6/26/01	-1	PI01	14	28						5/6.0	1/4.0		1/4.4	3/1.1			
7/22/01	-2	PI01	14	18						2/4.9	4/7.4	1/16.5	1/4.6	3/1.4	2/1.1	1/7.9	
8/20/01	-1	PI01	13	26						4/5.4			2/5.7	2/1.6			
10/21/01	1	PI01	13	31													
total fish										11	5	1	4	8	2	1	
Rolling																	
Island																	
6/11/01	1	RI01	10	22	2/5.6					3/2.9			2/9.9	6/0.8			
7/8/01	2	RI01	11	15										5/0.7	3/4.1		
8/4/01	1	RI01	15	17	5/NM					1/3.4			1/1.3	2/2.0	1/1.5		
10/21/01	1	RI01	11	31						4/7.9			1/12.9	1/3.6	9/5.1		
total fish					7					8			4	14	13		
Seawall																	
Picnic															.		
6/22/01	0	SP01	12	27										3/0.8	1/1.2		
7/22/01	-1	SP01	13	16						4/4.9			3/4.3	32/1.6	3/1.7		
8/17/01	0	SP01	13	32										24/2.7	3/4.2		
total fish										4			3	59	7		
Ship																	
Harbor																	
6/16/01	2	SH02	17	31									1/10.0				
		SH03	16	23									1/9.7				
7/21/01	0	SH01	13	24													
		SH02	14	21									2/7.6	5/2.0			
		SH03	14	20										1/1.8			
8/20/01	-2	SH01	12	31													
		SH02	12	28						1/4.1			1/5.5	2/2.5			
		SH03	13	31										1/2.5	1/4.0		
10/3/01	0	SH01	13	37											1/5.1		
		SH02	13	22						1/5.7			4/10.1		3/5.1		
		SH03	13	37											1/6.5		
total fish										2			9	9	6		

Schooner																	
Head Rd																	
7/2/01	1	SR01	16	26									1/11.4				
		SR02	15	25													
7/25/01	-1	SR01	14	15						1/6.2			1/NM	2/1.9			
		SR02	15	15										3/3.9	1/2.2		
10/16/01	-3	SR01	12	29						1/7.2					1/6.2		
		SR02	12	33						1/7.3				3/4.1			
total fish										3			2	8	2		
Thompson																	
Island																	
6/10/01	0	TI01	26	28		23/4.4		3/4.3									
						250/1											
		TI02	16	25		33/4.3											
						110/1											
7/5/01	1	TI01	21	20			*100/1.8*	*200/2.2*									*800*
		TI02	25	20			11/1.6	8/2.5									2000
8/3/01	1	TI01	24	16		158/1.6	4/1.3	4/1.9									200
		TI02	24	20		19/1.6	200/NM	200/NM									250
9/19/01	-2	TI01	10	30		4/2.3	7/3.4	8/3.9									
		TI02	12	27		1/2.8											
total fish						598	*122*	*420*									*3250*

Thunder Hole																	
6/22/01	-1	TH01	12	31													
		TH02	11	29													
7/18/01	1	TH01															
7/24/01	-2	TH02															
		TH01	15	12						2/7.2					2/5.7		
		TH02	11	15											1/1.9		
8/19/01	1	TH01															
8/8/01	-1	TH02															
		TH01	14	31						1/6.5				1/2.8			
		TH02	14	22													
10/15/01	-1	TH01															
10/20/01	-2	TH02															
		TH01	11	30											3/5.7		
		TH02	12	34											2/7.2		
total fish										3				1	8		
Western																	
Point																	
6/20/01	1	WP01	13	32						3/1.3							
7/17/01	1	WP01	13	13						2/3.9			1/NM	3/1.2			
8/2/01	1	WP01	14	16						1/6.4							
9/30/01	1	WP01	14	26						1/5.6			2/13.0				
9/28/01	2	WP02	13	19						1/NM			4/NM				
total fish										8			7	3			

Appendix 3. Grass and algae abundance in tidepools for each sampling date. ZM = *Zostera marina*, SP = *Spartina* spp., AN = *Ascophyllum nodosum*, FV = *Fucus vesiculosus*, EF = *Ectocarpus fasciculatus*, BF = Brown filamentous, CC = *Chondrus crispus*, LS = *Laminaria saccharina*, LD = *Laminaria digitata*, AE = *Alaria esculenta*, EN = *Enteromorpha*, UL = *Ulva lactuca*, CM = *Chlorophyta* miscellaneous, PU = *Porphyra umbilicalis*, RP = *Rhodymenia palmate*, CA = *Crustose* algae, CD = *Corallina officinalis* (crust)

Pool ID	Date	ZM	SS	AN	FV	EF	BF	CC	LS	LD	AE	EN	UL	CM	PU	RP	CA	CD
AC01	6/7			1	2	2		2	1				1	2		2	5	2
AC01	7/7			2	2		4	2	2				4			3	5	3
AC01	8/1			1	1			3					3	1		3	5	3
AC01	8/1			1	1			3					3	1		3	5	3
AC02	6/7				3						5		1					
AC02	7/7				3		3	2			3		2			2	2	
AC02	8/1				3		1				3		1			1		
AC02	9/27			3	3	5	2	1						2		1	2	
AC03	6/7			2	2						2		3	4				
AC03	7/7				2	3	3						2			2		
AC03	8/1				2		1						3	2		1		
AC03	9/27			4	4		3	3	1		1					1	3	
AC04	6/7			2				2			2	3	3	2			3	
AC04	7/7			2	2		2	2			2			2		2	3	2
AC04	8/1							3					2	3		1	2	2
AC04	9/27			2										2			2	
AC05	6/7																	
AC05	7/7																	
AC06	6/7						3					2	2					
AC06	7/7				1		3	2				3	1	2				
AC06	8/1											2		2				
AC06	9/27							2						2			1	
AC07	6/7			2	2						3		2	3				
AC07	7/7			1	2		2	3						4			2	2
AC07	8/1							2						2				
AC07	9/27			3	1									4				
AC08	6/7			3			3							1				

AC08	7/7			3	2		3	2						2			2	
AC08	8/1			2	1	1		1	1		1			1				
AC08	9/27			3	3									2				
BHB1	6/23				1	4	3	2					2	3			3	
BHB1	8/4			2	3	2	1	1	1				3	1		1	3	4
BHB1	9/15			2	2	3	3		1				3	3			2	1
BHB2	6/23			1	2		3	1		2				3				
BHB2	8/4			1	1	3	2	1	1				4	1		1	2	2
BHB2	9/15			2	2	3	3		3	1	3		3	3			4	4
BHB2	10/17					1	2	3	1					2			2	2
BHB3	6/23			2	2	2		2	2				3	4				
BHB3	8/4			2	2	3	2	2	2	1	1		3	2		2	2	2
BHB3	10/17			3	2	1		1	1				2				2	1
BL01	6/8																	
BL01	7/3						1	2						1			5	2
BL01	8/5				1			2					1				5	2
BL01	9/18			1	1			2			1						5	
BL02	6/8																	
BL02	7/3						2						1				3	
BL02	8/5			1				1					1				3	
BL02	9/18			1	1			1										
DP01	6/8			4	3	3			5				2	3				3
DP01	7/31			4	3	3		2			4			3		2	3	
DP01	9/17			4	4	3	3		4	4	4		2	2	2		1	
GM01	6/24			1	2	3		3	3	3	2		2		2		3	3
GM01	7/23			2	3	3	3	3	4	4	2		3	2		3	4	3
GM01	10/8			2	2	2	2	4	3	3	2		2	2		2		2
GM02	6/24			3	1	3		4	2	3	2		3	3		3		
GM02	7/23			3	2	3		3	1	1	2		3	2		3		2
GM02	10/8			2	3	3			5	2	3		5	2			2	2
LH01	6/23									3	5			2			2	
LH01	7/24					1	2			1	4		1		1	2	3	1
LH02	6/23			3	1		3	3		2			4	4			4	
MI01	6/19				3	3	3	3		2	3		1		1	1	3	2
MI01	7/19	1	1		4			3	2	3	4		3	3		3	3	3

MI01	10/21			4	4		1	2					3				3	
MI02	6/19			3	1	3							2	2			3	
MI02	7/19			4	5	3		3	2	2	2		3	3		2	4	
NN01	7/6			2	4		2	4	2		2	2					3	3
NN01	7/30			2	3		2	4						3			3	3
NN01	7/6			3	2		3	3						3			3	2
NS01	7/30			3	3	3	3	4	2	1	1			4		2	3	3
NS01	9/18			4	4	1	1	4						3			4	
NS02	9/18			4	4			3						2			4	
OP01	7/7			4	3	3	2	2	3	3			2	2	2		3	3
OP01	7/18			5	4	4	2	2	4	3	2		4	3		4	4	4
OP01	8/7			4	3	4	2	4	3	2	1		3	3		1	3	2
OP01	9/29			4	4	4	2	4	3				4	3			3	3
OP02	7/8			2	2	2		1	1		1			1		2	2	3
OP02	8/7			2	3	3	2	2	1		2					3	3	2
OP02	9/29			4	4	3	3				3						5	3
OP03	7/7			4	3	2	3	3	2	2	3		3	3		2	4	3
OP03	8/7			3	2	3	4	3	2	3	2		3	4		2	4	3
OP03	9/29			4	4	4		3	3	2	1		3	3			4	3
PI01	6/26																	
PI01	7/22			2	3		2		1					2			3	2
PI01	10/1			4	4	4	2	4	3				4	3			3	3
RI01	6/11																	
RI01	7/8			4	3	3	3	3	3	2	3	3	2	3		3	5	5
RI01	8/4			3	2	2	3	3	3	3	2		3	3		2	3	3
RI01	10/21			3	3	2	2	3	3	2	1	1	2	2		1	2	3
SH02	10/3			2	3		2	3	4				2			2	5	5
SH02	6/16			4	4	4	2	3	3	3	3		3	3	3	2	1	
SH03	6/16				3	3		3	3	4	4		3			2	3	2
SH03	10/3			3	1	2		3	3				2				3	
SP01	6/22			1	1				4	2			2		2		3	2
SP01	7/22			2	2	3		5	4	4	4		3	2		3	3	3
SR01	10/16			2	2	2	1		5	2	2		2				2	1
SR02	10/16			2	2	2	1	2	2	2	2		3			1		
TH01	6/22				1					5	4					1	2	

TH01	7/24				1			1		4	4				1	2	3	1
TH01	8/8				3		2	2	2	5	5		1			4	2	2
TH02	6/22			1	2	4	2		2	1			4	3	2		2	3
TH02	7/18			4	4	4	3	3	2	2			4	4		4	5	1
TH02	8/8			3	4	4	4	2	3	3	2		5	4		4	4	4
TH02	10/20			4				3	4	4						1	4	
TI01	6/10			3														
TI01	7/5																	
TI01	8/3		4	3														
TI02	6/10			2														
TI02	7/5																	
TI02	8/3			2														
TR01	9/19			4														
TR02	9/19			4														
WP01	6/20			1	1	3			2	1			3	4			3	3
WP01	6/20			1	1	3			2	1			3	4	3		3	3
WP01	7/17			4	4	4	3	3	3	1	2		3	2		2	2	3
WP01	8/2			3	2	3	2	3	2				3	3		2	2	3
WP01	9/30			4	4	4	2		3	3			4	4		2	2	5
WP02	9/28			4	4	3	1	3									3	

Appendix 4. Invertebrate abundance in tidepools for each sampling date. SB = *Semibalus balanoides*, ME = *Mytilus edulis*, Periwinkles, LL = *Littorina littorea*, LO = *Littorina obtusata*., LS = *Littorina saxatilis*, BC = *Buccinum undatum*, AT = *Acmaea testudinalis*, MP = *Microciona prolifera*, CR = Crabs, PL = *Pagarus longicarpus*, AF = *Asterias forbesi*, OA = *Ophiopholis aculeata*, SD = *Strongylocentrotus droebachiensis*, GS = *Gammarus spp.*, IS = Isopod spp., NU = Nudibranchia, PO = Family: Polynoidae, TV = *Tetrastemma vermiculum*, AN = *Anemone*, CF = *Cucumaria frondosa*, Eg = eggs, ED = eggs donut form, EP = eggs droplet form, ER = eggs rope form, PS = *Palaemonetes spp.* A score of 0 meant the species was absent, 1 that a couple were present, 3 that they were common, and 5 that they were extremely abundant or dominant in the pool. Scores of 2 and 4 were given if the observers determined that the species was intermediate to the other scores.

Pool ID	Date	SB	ME	LL	LL	LO	LS	BC	AT	MP	CR	PL	AF	OA	SD	GS	IS	NU	PO	TV	AN	CF	EG	ED	EP	ER	PS
AC01	6/7	2	2	3	3			3		3					3						5						
AC01	7/7	3	3	3	3			2	4	3	2				2	1		1			4						
AC01	8/1	4	2	2	2	2		1	2	3	3	1						1						1			
AC01	8/1	4	2	2	1	1		1	2	3	3	1						1					1	1			
AC02	6/7		5	2						1						2											
AC02	7/7	3	5							1						3					1						
AC02	8/1	2	5	2												3											
AC02	9/27		5	1												3											
AC03	6/7	4	2													3											
AC03	7/7	4	5	4	2	4		1	3							4	3			1							
AC03	8/1	2		3												3											
AC03	9/27		5	1							1					3											3
AC04	6/7	5		5				3	3																		
AC04	7/7	5	3	5	5			4	4		4		1		1	2		1		1	4		2		1	1	
AC04	8/1	3	3			3		3	3		3	1				2							1				
AC04	9/27	3			5	5		1			3					3					1				3		
AC05	6/7																										
AC05	7/7																										
AC06	6/7	3	4	4												2											
AC06	7/7	4	4	5				4								2											
AC06	8/1	4	4	3					1							1											
AC06	9/27	5	5		4			1			1					1											
AC07	6/7	5	5	3	3																						
AC07	7/7	3	5	4	4			3																			

AC07	8/1	4	4			3			1							2											
AC07	9/27	5	5	5																							
AC08	6/7	5	5	3	3				2		3					3											
AC08	7/7	4	4	4	4			3	1		3					2											
AC08	8/1	3	4		4	4		2	2		3					3							1				
AC08	9/27	4	4		3	3		3	1		2					3											
BHB1	6/23	2	2	3	2	2		2				2				2	1			2							
BHB1	8/4		2		2				3	1	2	3	3				2	1									
BHB1	9/15	3	2		3	3		2			3		3			4											
BHB2	6/23	2	3	2								2				2	2	1					2				
BHB2	8/4		1		1							3	3											4			
BHB2	9/15	3	2		3	3		2			3		3			4			5								
BHB2	10/17	1		2				1			2	4	3			3	4		2			2					
BHB3	6/23	3	3	3	2	2		3	3			3	5		3	2	2	2	1	1			2	2			
BHB3	8/4	2	2		2			1	3		4	3	4	1	2	2	1	2		2			2				
BHB3	10/17		1								4	4	3		2	2	4	2	2								
BL01	6/8										2																
BL01	7/3	4	4	2	2			2	2		3	3			1						3		2		2		
BL01	8/5	3	4	3				2	2	1	2					1					4				2		
BL01	9/18	4	2	2				2																			
BL02	6/8	3									4																
BL02	7/3	3	1	3	3			1	1	1	5		2			1					1	1	2			2	
BL02	8/5	3	3		3			2			5					4					1						
BL02	9/18	4		3							5		5														
DP01	6/8	2		3				2	2		5	2	3			4							3				2
DP01	7/31	2	2		4	4		3	3		4	3	3			3							1				2
DP01	9/17	2	2		2	2		2	4	3	5	4	3	2		2	2	3			1	3					2
GM01	6/24	1	2	2				1		2			2		3	3				1							
GM01	7/23	3	3		2	2		2	2	3	2	1	3		3	2								3			
GM01	10/8	1	3	1						3	3		3		3	1											
GM02	6/24	2	5	2	2						1					2		1					2				
GM02	7/23		2			2		2			2		1			2		1						3		3	1

GM02	10/8	2	3	2						2	3					2											
LH01	6/23		5					2	2			1	3		3	5	3										
LH01	7/24	2	4		2					3			3		4	4											
LH02	6/23	3	4	3	3			2	3		4		3	1	2	2											
MI01	6/19	2	3	2	2				1	1					1	5							1				
MI01	7/19	4	5		4				2	3	1		1		2	5	2				4			1			
MI01	10/21	3	4			3				4	3	3	2		4	2											2
MI02	6/19	3	3	3	3			1	4	3	2	1	1	1	5	2					3		1				
MI02	7/19	3	3		3	3		3	4	2	3		3		4	2	2			1					2		
NN01	7/6	3	2	3	2	2		3	3	2	4					3	2										
NN01	7/30	3	2		4	4	4	3	3	3	4		1		2	2	2			1							
NN01	7/6	3	2	3	2	2		2	3	2	3	1				3				1			2		2		
NS01	7/30	4	2		4	4		3	3	2	4	1	2		1	2		2									
NS01	9/18	4	3		4	4		2	1	3	1	3	1			2		1	2								
NS02	9/18	4	2		4	4		2			2	2				2											
OP01	7/7	3	3	3					3	2	3		3		3	2	1	2					1	1			
OP01	7/18	3	4		3	3		4	3	1	4	2	4		4	4	3	1	2	1	3		1				
OP01	8/7	2	2		3	3		1	1	2	2		3		3	4		3									
OP01	9/29	1	3		3	3					4		3		2	4		3									
OP02	7/8	2	2	3	2	3		3	4		2		3			3	2				2		1		1		
OP02	8/7	4	2		3	3		4	3		1		4		2	2		1			2						
OP02	9/29	1	1	2									3		1				1								
OP03	7/7	3	3	2	2				3	3	3		1		3	2		4	1	1	3		3		3		1
OP03	8/7	3	4		3	3		2	3	2	2		3		4	3		2						1			1
OP03	9/29	3	3	3					1		3		1		2	1			1								
PI01	6/26	2		3							4	3				3		1	1			1	1		1		
PI01	7/22	2	2		4			2	3	1	4	5	1			2		1						3	3		3
PI01	10/1	1	3		3	3					4		3		2	4		3									
RI01	6/11																										
RI01	7/8	3	3	4	4			3	3	3	3		3		2	3	3	2					3		3		3
RI01	8/4	3	3		4	4	4	3	3	2	3		2		2	2		1									
RI01	10/21	1	3		4	4	4	2		3	3		1		1	2	1	1	1						2		

SH02	10/3				2	2				4	4		1			3											
SH02	6/16	3	1	3	2		2	1	3		4		1			2	1	4			1		3	3			
SH03	6/16		2							2	3	3	3			3		1					1	1			
SH03	10/3	3	4	3				2		1	2	2				1											1
SP01	6/22	2	2	5	5			2	2	3	3	4	3		1	2	2	2		2			3	3			
SP01	7/22	3	4	5	3	3		3	3	3	3	3	3			3	2	3	2				2	1	1		3
SR01	10/16	4	3		3	3		2			2		2			3	1	2									
SR02	10/16	3	3		3	3		3			2					3	2	1	2								
TH01	6/22	1	5	1							1		3			5	4		1								
TH01	7/24	2	4						2	4	3		2			3								2			
TH01	8/8	2	5							3			1			2											
TH02	6/22	2	2		3	3		1			2		5		2	3	3			2							
TH02	7/18	1	1		3	3		3	3		3	4	3		3	5	3		3								
TH02	8/8	2	4			3		2	2		3		2		1	4	4		2	1	2						
TH02	10/20	4	4	1						3	1				2	3		1									
TI01	6/10				5											3											1
TI01	7/5	2	3		3											3							4				
TI01	8/3				4	4										3											
TI02	6/10	2			2																						
TI02	7/5	3	3			3										2											
TI02	8/3			3												3											
TR01	9/19				3											3											3
TR02	9/19		2		3											3											3
WP01	6/20		3	3	2	1		1	2	2	2	1				3	3	1					2	2			
WP01	6/20		3		3	3		1	2	2	2	1				3	3	1						2			
WP01	7/17	2	4	4				3	3	3	3				1	4	4	1					1				
WP01	8/2		2		3	3		2		2	2		2			3	3		1	1							
WP01	9/30		2		3	3		3			2					1			1								
WP02	9/28	3	2	3				2	3	3	3		2		1	2		4									

Appendix 5. Fish species captured during 2002 inventory of Seal Cove. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling) used is identified as well as GPS coordinates of location of fishing effort. Some visual observations are also reported. Fish lengths are reported in Appendix 6. Abbreviation identification is located in Appendix 1. “Saltwater” indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
					#	#	#	#	#	#	#	#	#	#	#	#	#	#
6/13	15:30	S	4903758	547907	1	1	4											
		D	4903769	547862	116													
		D	4903780	547869					1									
6/14	7:00	F	4903750	547916	3													
6/14	16:00	F	4903750	547916													1	
		MA	4903808	547857														
		MB	4903774	547862	42		1											
		MC	4903780	547869														
		MD	4903759	547867														
		ME	4903760	547874														
		MF	4903762	547881			2											
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899	4													
6/15	7:00	F	4903750	547916	1													
		F	SALTWATER		1													
		MA	4903808	547856														
		MB	4903774	547862	7		1											
		MC	4903780	547869	7		1											
		MD	4903758	547867														
		ME	4903760	547873	4													
		MF	4903762	547881	1													
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899	5		4											

6/15	11:30	MA	4903808	547856														
		MB	4903774	547862	4													
		MC	4903780	547869	27		2											
		MD	4903758	547867														
		ME	4903760	547873			2											
		MF	4903762	547881														
		MG	4903766	547888														
		MH	4903709	547867			1											
6/15	15:30	F	4903750	547916	2													
		F	SALTWATER															
		MA	4903808	547856			1											
		MB	4903774	547862	1													
		MC	4903780	547869	28		2											
		MD	4903758	547867														
		ME	4903760	547873			1											
		MF	4903762	547881														
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899														
		BS	4903783	547865	35		1									1			
		V	4903772	547893					1									
8/20	16:30	MA	4903808	547856														
		MB	4903774	547862			4											
		MC	4903780	547869			1											
		MD	4903758	547867														
		ME	4903760	547873														
		MF	4903762	547881	1		1											
		MG	4903766	547888	2													
		MH	4903709	547867														
		MI	4903735	547899	2													
		V	4903772	547893						1								

8/21	15:30	F	4903750	547916	17													
		MA	4903808	547856														
		MB	4903774	547862	1		9											
		MC	4903780	547869			4											
		MD	4903758	547867	24		1											
		ME	4903760	547873	47													
		MF	4903762	547881														
		MG	4903766	547888	20													
8/21	23:00	D	4903840	547848						2				52				
8/22	6:30	F	4903750	547916	3													
		MZ	4903999	547827	2													
		MA	4903808	547856	5													
		MB	4903774	547862	1													
		MC	4903780	547869			6											
		MD	4903758	547867	6													
		ME	4903760	547873	15													
		MF	4903762	547881	1		2											
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899														
8/22	14:00	MA	4903808	547856	90													
		MB	4903774	547862	5													
		MC	4903780	547869	2		6											
		MD	4903758	547867	7		8											
		ME	4903760	547873	10													
		MF	4903762	547881	1													
		MG	4903766	547888														
		MH	4903709	547867														
		D	4903879	547841	8													
		D	4903766	547888										5				
		V	4903893	547849	VA				1									

8/23	6:00	F	4903750	547916	13													
		MZ	4903999	547827	8													
		MA	4903808	547856	5													
		MB	4903774	547862														
		MC	4903780	547869	1													
		MD	4903758	547867			13											
		ME	4903760	547873	6													
		MF	4903762	547881														
		MG	4903766	547888	6													
		MH	4903709	547867														
		MI	4903735	547899	2													
		D	4903925	547847	204		2											
		D	4903888	547840										4				
8/23	12:00	MA	4903808	547856	59													
		MB	4903774	547862														
		MC	4903780	547869			1											
		MD	4903758	547867			1											
		ME	4903760	547873														
		MF	4903762	547881	3													
		MG	4903766	547888	7													
		MH	4903709	547867	24													
		MI	4903735	547899	5													
		AG	4903419	547505								1						
TOTAL					902	1	82	0	3	3	0	1	0	61	1	0	1	0
PERCENT					85.5	0.1	7.8		0.3	0.3		0.1		5.8	0.1		0.1	

Appendix 6. Average fish length of each species captured during 2002 inventory of Seal Cove. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling) used is identified. as well as GPS coordinates of location of fishing effort. Abbreviation identification is located in Appendix 1. “Saltwater” indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
					Cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
6/13	15:30	S	4903758	547907	5.3	4.4	3.9											
		D	4903769	547862	4.3													
		D	4903780	547869					5.5									
6/14	7:00	F	4903750	547916	5.3													
6/14	16:00	F	4903750	547916													3.5	
		MA	4903808	547857														
		MB	4903774	547862	4.5		5											
		MC	4903780	547869														
		MD	4903759	547867														
		ME	4903760	547874														
		MF	4903762	547881			3.9											
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899	4.9													
6/15	7:00	F	4903750	547916	5.2													
		F	SALTWATER		7.5													
		MA	4903808	547856														
		MB	4903774	547862	4.6		4.9											
		MC	4903780	547869	4.6		4.9											
		MD	4903758	547867														
		ME	4903760	547873	4.5													
		MF	4903762	547881	4.3													
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899	4.9		4.4											

6/15	11:30	MA	4903808	547856														
		MB	4903774	547862	4.4													
		MC	4903780	547869	5.1		4.5											
		MD	4903758	547867														
		ME	4903760	547873			4.4											
		MF	4903762	547881														
		MG	4903766	547888														
		MH	4903709	547867			4.2											
6/15	15:30	F	4903750	547916	5.9													
			SALTWATER															
		MA	4903808	547856			3.9											
		MB	4903774	547862	4.3													
		MC	4903780	547869	4.8		3.9											
		MD	4903758	547867														
		ME	4903760	547873			4.3											
		MF	4903762	547881														
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899														
		BS	4903783	547865	5		3.9								5.2			
		V	4903772	547893					NM									
8/20	16:30	MA	4903808	547856														
		MB	4903774	547862			4.8											
		MC	4903780	547869			4.7											
		MD	4903758	547867														
		ME	4903760	547873														
		MF	4903762	547881	6.9		4.7											
		MG	4903766	547888	5.9													
		MH	4903709	547867														
		MI	4903735	547899	6.9													
		V	4903772	547893						NM								

8/21	15:30	F	4903750	547916	5.9													
		MA	4903808	547856														
		MB	4903774	547862	8		4.3											
		MC	4903780	547869			3.7											
		MD	4903758	547867	6.6		5.2											
		ME	4903760	547873	5.8													
		MF	4903762	547881														
		MG	4903766	547888	6.1													
8/21	23:00	D	4903840	547848						5.1				7				
8/22	6:30	F	4903750	547916	5													
		MZ	4903999	547827	6.3													
		MA	4903808	547856	5.1													
		MB	4903774	547862	6.3													
		MC	4903780	547869			3.4											
		MD	4903758	547867	7													
		ME	4903760	547873	6.4													
		MF	4903762	547881	4.7		4.3											
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899														
8/22	14:00	MA	4903808	547856	5.6													
		MB	4903774	547862	5.9													
		MC	4903780	547869	5.6		4.5											
		MD	4903758	547867	6.8		4.5											
		ME	4903760	547873	5.6													
		MF	4903762	547881	6.5													
		MG	4903766	547888														
		MH	4903709	547867														
		D	4903879	547841	2.7													
		D	4903766	547888										6.4				
		V	4903893	547849	NM				NM									

8/23	6:00	F	4903750	547916	2.4													
		MZ	4903999	547827	5.4													
		MA	4903808	547856	5.6													
		MB	4903774	547862														
		MC	4903780	547869	7.5													
		MD	4903758	547867			3.3											
		ME	4903760	547873	5.4													
		MF	4903762	547881														
		MG	4903766	547888	6.4													
		MH	4903709	547867														
		MI	4903735	547899	NM													
		D	4903925	547847	3		2.6											
		D	4903888	547840										7.6				
8/23	12:00	MA	4903808	547856	5.3													
		MB	4903774	547862														
		MC	4903780	547869			4.4											
		MD	4903758	547867			4.4											
		ME	4903760	547873														
		MF	4903762	547881	5.8													
		MG	4903766	547888	6.2													
		MH	4903709	547867	6.3													
		MI	4903735	547899	6.3													
		AG	4903419	547505								25						

Appendix 7. Fish species captured during 2003 inventory of Seal Cove. The date and GPS coordinate placement of the seines are identified. Fish lengths are reported in Appendix 8. Abbreviation identification is located in Appendix 1.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
			#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
6/16	4904025	547825															
	4903758	547907															
	4903594	547850	17		2		1										
7/15	4904025	547825						1									
	4903758	547907						1									
7/16	4903594	547850	71		1			2									
8/17	4904025	547825							1								
	4903758	547907															
	4903594	547850	168		3			23									
TOTAL			256	0	6	0	1	27	1	0	0	0	0	0	0	0	0
PERCENT			88.0		2.1		0.3	9.3	0.3								

Appendix 8. Average fish length of each species captured during 2003 inventory of Seal Cove. . The date and GPS coordinate placement of the seines are identified. Abbreviation identification is located in Appendix 1.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
			cm	cm	cm	cm	cm	cm	Cm	cm	Cm	cm	cm	cm	Cm		
6/16	4904025	547825															
	4903758	547907															
	4903594	547850	4.9		3.9		5.4										
7/15	4904025	547825						11									
	4903758	547907						8.5									
7/16	4903594	547850	5		3		6.5										
8/17	4904025	547825							2.2								
	4903758	547907															
	4903594	547850	2.8		2.6			3.5									

Appendix 9. Fish species captured during 2002 inventory of Somes Sound. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling, visual) used is identified as well as GPS coordinates of location of fishing effort. Fish lengths are reported in Appendix 10. Abbreviation identification is located in Appendix 1. . “Saltwater” indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
					#	#	#	#	#	#	#	#	#	#	#	#	#	#
7/1	15:30	D	4913229	553410					9									
		D	4913206	553462					1									
		D	4913129	553487		11		18	4									
		D	4913927	553335	10	3		2										
		V	4913088	553471														
7/1	13:40	MA	4913074	553474					1									
		MB	4913099	553474														
		MC	4913097	553456														
		MD	4913139	553475														
		ME	4913130	553461														
		MF	4913132	553441														
		MG	4913128	553425														
		MH	4913229	553427														
		MI	4913403	553445					1									
7/3	13:00	F	4913791	553638	2													
		F	SALTWATER		322	1												
		V	SALT MARSH		A				A									
		D	4913727	553472	1	1												
7/3	16:00	MA	4913074	553474														
		MB	4913099	553474														
		MC	4913097	553456														
		MD	4913139	553475														
		ME	4913130	553461														
		MF	4913132	553441														
		MJ	4913676	553541	30													
		MK	4913765	553374	43													
7/4	13:00	F	4913791	553638	2													
		F	SALTWATER		26	3												
		V	4913762	553641	AYOY	A	A	A	FEW									

Appendix 9. Cont.

7/4	14:30	MA	4913074	553474									2					
		MB	4913097	553474														
		MC	4913097	553456														
		MD	4913139	553475														
		MF	4913132	553441														
		MG	4913128	553425														
		MH	4913229	553427														
		MI	4913403	553445	2													
		MJ	4913676	553541	152													
		MK	4913676	553374	48													
9/6	15:30	MC	4913765	553374	198													
9/7	10:30	MA	4913796	553665														
		MB	4913676	553541	81													
		MC	4913765	553374	11													
		MD	4913403	553445														
		ME	4913128	553425														
		MF	4913135	553452														
		MG	4913139	553475														
		MH	4913074	553474														
		LS	4913129	553487		1				394				1				
9/7	10:30	MA	4913796	553665	71													
		MB	4913676	553541														
		MC	4913765	553374	70													
		MD	4913403	553445														
		ME	4913128	553425														
		MF	4913135	553452	1													
		MG	4913139	553475														
		MH	4913074	553474														

9/8	12:00	MA	4913796	553665	306													
		MB	4913676	553541	74													
		MC	4913765	553374	56													
		MD	4913403	553445														
		ME	4913128	553425	1													
		MF	4913135	553452														
		MG	4913139	553475														
		MH	4913074	553474														
		LS	4913129	553487						318								
9/8	18:00	MA	4913796	553665	145													
		MB	4913676	553541	107													
		MC	4913765	553374	11													
		MD	4913403	553445														
		ME	4913128	553425														
		MF	4913135	553452														
		MG	4913139	553475														
TOTAL					1770	20	0	20	16	712	0	0	2	1	0	0	0	0
PERCENT					69.7	0.8		0.8	0.6	28.0			0.1	<0.1				

Appendix 10. Average fish length of each species captured during 2002 inventory of Somes Sound. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling, visual) used is identified as well as GPS coordinates of location of fishing effort. Abbreviation identification is located in Appendix 1. “Saltwater” indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
					cm	cm	Cm	cm	cm	cm	Cm	cm	cm	cm	cm	Cm	cm	cm
7/1	15:30	D	4913229	553410					6.5									
		D	4913206	553462					6.1									
		D	4913129	553487		2.8		3.3	6.3									
		D	4913927	553335	4.8	2.2		3.6										
		V	4913088	553471														
7/1	13:40	MA	4913074	553474					4.2									
		MB	4913099	553474														
		MC	4913097	553456														
		MD	4913139	553475														
		ME	4913130	553461														
		MF	4913132	553441														
		MG	4913128	553425														
		MH	4913229	553427														
		MI	4913403	553445					33									
7/3	13:00	F	4913791	553638	NM													
		F	SALTWATER		6.1	5.4												
		V	SALT MARSH		A				A									
		D	4913727	553472	1	3.9												
7/3	16:00	MA	4913074	553474														
		MB	4913099	553474														
		MC	4913097	553456														
		MD	4913139	553475														
		ME	4913130	553461														
		MF	4913132	553441														
		MJ	4913676	553541	5.7													
		MK	4913765	553374	6.4													
7/4	13:00	F	4913791	553638	7.2													
			SALTWATER		6.5	6.5												
		V	4913762	553641	NM	NM	NM	NM	NM									

7/4	14:30	MA	4913074	553474									14.1					
		MB	4913097	553474														
		MC	4913097	553456														
		MD	4913139	553475														
		MF	4913132	553441														
		MG	4913128	553425														
		MH	4913229	553427														
		MI	4913403	553445	7.2													
		MJ	4913676	553541	6.3													
		MK	4913676	553374	5.8													
9/6	15:30	MC	4913765	553374	4.9													
9/7	10:30	MA	4913796	553665														
		MB	4913676	553541	6.4													
		MC	4913765	553374	7.2													
		MD	4913403	553445														
		ME	4913128	553425														
		MF	4913135	553452														
		MG	4913139	553475														
		MH	4913074	553474														
		LS	4913129	553487		2.5				6.9				9.5				
9/7	10:30	MA	4913796	553665	5.6													
		MB	4913676	553541														
		MC	4913765	553374	5.9													
		MD	4913403	553445														
		ME	4913128	553425														
		MF	4913135	553452	7.3													
		MG	4913139	553475														
		MH	4913074	553474														

Appendix 10. cont.

9/8	12:00	MA	4913796	553665	5.2													
		MB	4913676	553541	6.7													
		MC	4913765	553374	5.4													
		MD	4913403	553445														
		ME	4913128	553425	5.4													
		MF	4913135	553452														
		MG	4913139	553475														
		MH	4913074	553474														
		LS	4913129	553487						NM								
9/8	18:00	MA	4913796	553665	4.8													
		MB	4913676	553541	5.9													
		MC	4913765	553374	4.8													
		MD	4913403	553445														
		ME	4913128	553425														
		MF	4913135	553452														
		MG	4913139	553475														

Appendix 11 Fish species captured during 2003 inventory of Somes Sound. The date and GPS coordinate placement of the seines are identified. Fish lengths are reported in Appendix 12. Abbreviation identification is located in Appendix 1. “Saltwater” indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
			#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
6/19	4913129	553487		149													
	4913688	553473		56		78	1	2					2				
	4913927	553335		213		287							1				
7/17	4913129	553487				1		1								95	
	4913688	553473	17	5		250	1	7				1				195	
	4913927	553335	31			4	17	60					1				
8/16	4913129	553487									168						
	4913688	553473				5		17									
	4913927	553335	15					71									
TOTAL			63	423	0	625	19	158	0	0	168	1	4	0	0	290	
PERCENT			3.6	24.2		35.7	1.1	9.0			9.6	0.1	0.2			16.6	

Appendix 12. Average fish length of each species captured during 2003 inventory of Somes Sound. The date and GPS coordinate placement of the seines are identified. Abbreviation identification is located in Appendix 1.

Date	northing	Easting	FUHE	GAAC	APQU	PUP U	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
			cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm		
6/19	4913129	553487		2.8													
	4913688	553473		2.2		2.9	12	8.9					14.2				
	4913927	553335		2.2		2.6							11.5				
7/17	4913129	553487				3.4		2.3								6.5	
	4913688	553473	1.9	2.9		4.2	6.5	6.9				4.2				4.9	
	4913927	553335	3.5			2.9	6.9	2.4					15.3				
8/16	4913129	553487									9.4						
	4913688	553473				4.3		5.6									
	4913927	553335	3.4					4.5									

Appendix 13. Fish species captured during 2002 inventory of Bass Harbor. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling, visual) used is identified as well as GPS coordinates of location of fishing effort. Fish lengths are reported in Appendix 14. Abbreviation identification is located in Appendix 1. “Saltwater” indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
Bass Habr					#	#	#	#	#	#	#	#	#	#	#	#	#	#
6/24	6:15	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004			2											
		ME	4900217	552040			1											
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110														
		MI	4900671	552303														
		F	4900236	551972														
6/24	19:10	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004														
		ME	4900217	552040			2											
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110			1											
		MI	4900671	552303														
		F	4900267	552011	2													
		F	SALTWATER			2	2	8										

6/25	9:50	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004				2										
		ME	4900217	552040			1		1									
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110														
		MI	4900671	552303														
6/25	17:50	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004			1	1										
		ME	4900217	552040		1												
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110														
		MI	4900671	552303														
		D	4900175	552004		4		3										
		D	4900267	552011		40												
		F	4900267	552011														
		F	SALTWATER															
6/26	18:30	V			A	A	A											
6/28	13:35	D	4902331	551469	18	1	11	14										
		D	4902091	551748	3													
6/28	16:30	MJ	4901572	552164	176													
		MK	4901569	552188	62				1	3								
		ML	4901544	552220	51				1									
		MM	4901528	552236	90													
		V	4901569	552188	A													
6/28	17:50	MK	4901569	552188	97													

8/23	13:00	D	4900175	552004		17				44								
		MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004			3											
		MD	4900187	551955			2											
		ME	4900185	551963			2											
		MF	4900227	552024			5											
		MH	4900671	552303			1											
		MI	4900238	552578	77				1									
8/24	9:30	MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004	7		8											
		MD	4900187	551955														
		ME	4900185	551963			1											
		MF	4900227	552024														
		MG	4900408	552110	61													
		MH	4900671	552303					2	8								
		MI	4900238	552578	16													
8/24	15:30	MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004			3											
		MD	4900187	551955														
		ME	4900185	551963														
		MF	4900227	552024														
		MG	4900408	552110														
		MH	4900671	552303														
		MI	4900238	552578	72	1												
		D	4900187	551955			2			19								
		D	4900238	552578	70													

8/25	10:30	MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004	2		4											
		MD	4900187	551955			1											
		ME	4900185	551963			2											
		MF	4900227	552024			1											
		MG	4900408	552110	128													
		MH	4900671	552303														
		F	4900267	552011		261	20	5		137								43
8/25	16:00	MA	4900126	4900126														
		MB	4900155	551945														
		MC	4900175	552004			1											
		MD	4900187	551955			4											
		ME	4900185	551963														
		MF	4900227	552024			1											
		MG	4900408	552110														
		MH	4900671	552303														
		MI	4900238	552578	46													
8/30	12:30	D	4900671	552303	11		18			46								
8/30	18:30	MJ	4901572	552164	25			2										
		MK	4901569	552188	8		3											
		ML	4901544	552220	1													
		MM	4901528	552236														
		MN	4901992	551859														
		MP	4902213	551585														
		MQ	4902331	551469	28													

8/31	9:40	MJ	4901572	552164	16				1									
		MK	4901569	552188	2													
		ML	4901544	552220	1													
		MM	4901528	552236	46													
		MN	4901992	551859	7													
		MO	4902091	551748														
		MP	4902213	551585														
		MQ	4902331	551469	3													
		LS	4901991	551802	41		10	11		26				41				
9/1	19:00	MJ	4901572	552164	138													
		MK	4901569	552188	2													
		ML	4901544	552220	3													
		MM	4901528	552236	197													
		MN	4901992	551859	8													
		MP	4902213	551585	338													
		MQ	4902331	551469	157													
TOTAL					2010	327	113	46	7	283	0	0	0	41	0	0	0	43
PERCENT					70.0	11.4	3.9	1.6	0.2	9.9	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.5

Appendix 14. Average fish lengths of each species captured during 2002 inventory of Bass Harbor. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling, visual) used is identified as well as GPS coordinates of location of fishing effort. Abbreviation identification is located in Appendix 1. “Saltwater” indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
					cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
6/24	6:15	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004			4.4											
		ME	4900217	552040			4.7											
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110														
		MI	4900671	552303														
		F	4900236	551972														
6/24	19:10	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004														
		ME	4900217	552040			4.4											
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110			4.1											
		MI	4900671	552303														
		F	4900267	552011	5.1													
			SALTWATER			4.7	2.9	2.8										
6/25	9:50	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004				4.7										
		ME	4900217	552040			4.1		23.4									
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110														
		MI	4900671	552303														

6/25	17:50	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004			4.7	4.8										
		ME	4900217	552040		4.3												
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110														
		MI	4900671	552303														
		D	4900175	552004		2.4		3.1										
		D	4900267	552011		2.2												
		F	4900267	552011														
			SALTWATER															
6/26	18:30	V			NM	NM	NM											
6/28	13:35	D	4902331	551469	4.5	1.7	1.5	2.2										
		D	4902091	551748	4.5													
6/28	16:30	MJ	4901572	552164	5.2													
		MK	4901569	552188	5.6				27	7.9								
		ML	4901544	552220	4.6				29.5									
		MM	4901528	552236	4.7													
		V	4901569	552188	NM													
6/28	17:50	MK	4901569	552188	5.6													
8/23	13:00	D	4900175	552004		2.9				3.5								
		MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004			3.8											
		MD	4900187	551955			4.7											
		ME	4900185	551963			4.4											
		MF	4900227	552024			4.4											
		MH	4900671	552303			4.5											
		MI	4900238	552578	5.7				31									

Appendix 14 cont.

8/24	9:30	MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004	7.3		4.2											
		MD	4900187	551955														
		ME	4900185	551963			4											
		MF	4900227	552024														
		MG	4900408	552110	5.2													
		MH	4900671	552303					19.8	6.8								
		MI	4900238	552578	4.5													
8/24	15:30	MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004			4											
		MD	4900187	551955														
		ME	4900185	551963														
		MF	4900227	552024														
		MG	4900408	552110														
		MH	4900671	552303														
		MI	4900238	552578	4.8	4.5												
		D	4900187	551955			3.9			3.8								
		D	4900238	552578	2.2													
8/25	10:30	MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004	7.9		4											
		MD	4900187	551955			4.4											
		ME	4900185	551963					22.2									
		MF	4900227	552024			3.7											
		MG	4900408	552110	4.4													
		MH	4900671	552303														
		F	4900267	552011		3	3.8	4.7		3.8								3.1

Appendix 14. cont.

8/25	16:00	MA	4900126	4900126													
		MB	4900155	551945													
		MC	4900175	552004			4.8										
		MD	4900187	551955			4.8										
		ME	4900185	551963													
		MF	4900227	552024			3.8										
		MG	4900408	552110													
		MH	4900671	552303													
		MI	4900238	552578	7.1												
8/30	12:30	D	4900671	552303	2.7		3.1			2.6							
8/30	18:30	MJ	4901572	552164	5.7			4.9									
		MK	4901569	552188	4.7		4										
		ML	4901544	552220	3.9												
		MM	4901528	552236													
		MN	4901992	551859													
		MP	4902213	551585													
		MQ	4902331	551469	4.6												
8/31	9:40	MJ	4901572	552164	4.9				20.5								
		MK	4901569	552188	4.1												
		ML	4901544	552220	3.9												
		MM	4901528	552236	4.7												
		MN	4901992	551859	4.2												
		MO	4902091	551748													
		MP	4902213	551585													
		MQ	4902331	551469	4												
		LS	4901991	551802	4.1		3.1	4.1		4				8.8			
9/1	19:00	MJ	4901572	552164	6.3												
		MK	4901569	552188	4.1												
		ML	4901544	552220	2.6												
		MM	4901528	552236	5.6												
		MN	4901992	551859	4.3												
		MP	4902213	551585	4.4												
		MQ	4902331	551469	4.9												

Appendix 15. Fish species captured during 2003 inventory of Bass Harbor. The date and GPS coordinate placement of the seines are identified. Fish lengths are reported in Appendix 16. Abbreviation identification is located in Appendix 1.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
			#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
6/21	4901578	552199	51	2	5	3		10			2						
	4902331	551469				8											
6/22	4900074	551927										1					
	4900874	552329	3	2	11	10		8				9	1				
7/16	4901578	552199	310					40									
	4902331	551469				9									2		
7/21	4900074	551927				5						127					
	4900874	552329	6	21		4						43					
8/17	4900074	551927		7		1		5			2						
	4900874	552329	12	1	52	49		12									
	4901578	552199	25					8									
	4913890	573957	93		30	5									3		
	4902331	551469				1									6		
TOTAL			449	31	93	84	0	73	0	0	2	180	1	0	11	0	0
PERCENT			48.6	3.4	10.1	9.1		7.9			0.2	19.5	0.1		1.2		

Appendix 16. Average fish length of each species captured during 2003 inventory of Bass Harbor. The date and GPS coordinate placement of the seines are identified. Abbreviation identification is located in Appendix 1.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
			cm	cm	cm	Cm	cm	cm	cm	cm	Cm	cm	cm	cm	cm		
6/21	4901578	552199	3.8	4.4	2.9	2.6		9			10.3						
	4902331	551469				5.1											
6/22	4900074	551927										4					
	4900874	552329	4.8	1.9	4.1	3.2		9				4.2	14				
7/21	4900074	551927				3.1						2.2					
	4900874	552329	1.5	2.4		3.3						6.2					
7/16	4901578	552199	5.8					3.8									
	4902331	551469				2.7									1.3		
8/17	4900074	551927		2.6		3.9		5.8			7.6						
	4900874	552329	2.3	2	3.4	4.4		5.9									
	4901578	552199	2.7					3.4									
	4913890	573957	3.9		2.8	3.2									6.6		
	4902331	551469				3.2									4.3		

Appendix 17. Fish species captured during 2002 inventory of Northeast Creek. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling, visual) used is identified as well as GPS coordinates of location of fishing effort. Fish lengths are reported in Appendix 18. Abbreviation identification is located in Appendix 1. "Saltwater" indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
NE Creek					#	#	#	#	#	#	#	#	#	#	#	#	#	#
7/8	20:00	D	4919296	553569	6	2	2		9									
7/9	19:30	F	4919320	553514	14	3												
		F	SALTWATER		46	1				1								
		MA	4919389	553435	52		1											
		MB	4919305	553474	209													
		MC	4919309	553488	155				1									
		MD	4919312	553504	54				1									
		ME	4919289	553563	56				1									
		MF	4919296	553569	106													
		MG	4919257	553589			5	2										
		MH	4918934	554294	165													
		MI	4918557	554681	120													
7/10	18:00	MA	4919389	553435	123													
		MB	4919305	553474	119													
		MC	4919309	553488	129	1				1								
		MD	4919312	553504	138				1									
		ME	4919289	553563	49				5									
		MF	4919296	553569	26				4									
		MG	4919257	553589	67		1											
		MH	4918934	554294	95													
		MI	4918557	554681	185													
		D	4919271	553614	10													
		D	4918986	555586	11													
7/10	19:00	F	4919320	553514	4	2	1											
		F	SALTWATER		2													

9/14	17:30	MA	4919389	553435	49													
		MB	4919305	553474	73													
		MC	4919309	553488	12													
		MD	4919312	553504	46													
		MF	4919289	553563	49			1	5									
		MG	4919257	553589	1													
		MH	4918934	554294	42													
		MI	4918557	554681	102													
		D	4919353	553488	317			50		17								
		D	4919309	553488			11	2										
9/15	18:00	MA	4919389	553435	7			1	1									
		MB	4919305	553474	62		1											
		MC	4919309	553488	50		3											
		MD	4919312	553504	1		2											
		MF	4919296	553569	174				1									
		MG	4919257	553589	5		2											
		MH	4918934	554294	6													
		MI	4918557	554681	36													
9/16	16:00	MA	4919305	553474	6			1	1									
		MB	4919305	553474	26													
		MC	4919309	553488	8				1									
		MD	4919312	553504	1													
		MF	4919296	553569	64				2									
		MG	4919257	553589	2													
		MH	4918934	554294	44			1										
		MI	4918557	554681	48		2	2								1		
		SS	4919271	553614	11			3		6				1				
		D	4918986	555586	1			5	1									
9/16	19:30	MB	4919305	553474	17													
		MC	4919309	553488	15													
		MF	4919296	553569	64		1		2									
9/17	7:30	MG	4919257	553589														
		MH	4918934	554294	6													
		MI	4918557	554681	5													
TOTAL					3291	9	32	68	36	25	0	0	0	1	0	1	0	0
PERCENT					95.0	0.3	0.9	2.0	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 18. Average fish length of each species captured during 2002 inventory of Northeast Creek. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling, visual) used is identified as well as GPS coordinates of location of fishing effort. Abbreviation identification is located in Appendix 1. “Saltwater” indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	Northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	ARFE	FUDI	TAAD	GAWH
					cm	cm	cm	cm	Cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
7/8	20:00	D	4919296	553569	3.9	3.9	1.7		7.9									
7/9	19:30	F	4919320	553514	5.8	5.2												
			SALTWATER		5.9	4.5				11								
		MA	4919389	553435	5.3		4.5											
		MB	4919305	553474	5													
		MC	4919309	553488	5.6				17.1									
		MD	4919312	553504	5.3				15.9									
		ME	4919289	553563	5.1				28.9									
		MF	4919296	553569	5.6													
		MG	4919257	553589			4.4	5.1										
		MH	4918934	554294	5.4													
		MI	4918557	554681	5.6													
7/10	18:00	MA	4919389	553435	5.5													
		MB	4919305	553474	5.2													
		MC	4919309	553488	5.7	NM				6.7								
		MD	4919312	553504	6.1				15.6									
		ME	4919289	553563	5.7				24.8									
		MF	4919296	553569	6.2				28.8									
		MG	4919257	553589	5.9		4.8											
		MH	4918934	554294	6													
		MI	4918557	554681	5.6													
		D	4919271	553614	1.4													
		D	4918986	555586	4.8													
7/10	19:00	F	4919320	553514	6	5	4.4											
			SALTWATER		NM													

9/14	17:30	MA	4919389	553435	6													
		MB	4919305	553474	5.8													
		MC	4919309	553488	5.8													
		MD	4919312	553504	6.5													
		MF	4919289	553563	6.9			4.5	29.2									
		MG	4919257	553589	4.5													
		MH	4918934	554294	6.3													
		MI	4918557	554681	6.3													
		D	4919353	553488	3.4			4.3		3.3								
		D	4919309	553488			3.5	3.9										
9/15	18:00	MA	4919389	553435	4.6			3.1	23.5									
		MB	4919305	553474	5.7		4											
		MC	4919309	553488	5.9		4.8											
		MD	4919312	553504	7.3		4.3											
		MF	4919296	553569	6.4				32.4									
		MG	4919257	553589	7.5		4.6											
		MH	4918934	554294	5.6													
		MI	4918557	554681	6.4													
9/16	16:00	MA	4919305	553474	5.8			4.7	23.5									
		MB	4919305	553474	5.5													
		MC	4919309	553488	5.9				25.4									
		MD	4919312	553504	5.4													
		MF	4919296	553569	6.6				35.3									
		MG	4919257	553589	7.4													
		MH	4918934	554294	6.1			5.5										
		MI	4918557	554681	6.6		6	5.4								7.2		
		SS	4919271	553614	6.3			3.4		3.7				2.4				
		D	4918986	555586	5.3			3.1	7.3									
9/16	19:30	MB	4919305	553474	5.5													
		MC	4919309	553488	5.6													
		MF	4919296	553569	6.6		4.7		26									
9/17	7:30	MG	4919257	553589														
		MH	4918934	554294	5.3													
		MI	4918557	554681	6.4													

Appendix 19. Fish species captured during 2003 inventory of Northeast Creek. The date and GPS coordinate placement of the seines are identified. Fish lengths are reported in Appendix 20. Abbreviation identification is located in Appendix 1.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
			#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
6/24	4919420	553142	81	26		80		8			2						
	4919356	553457	96	1	59	578		1				12					
	4919271	553614	7	1	3	9		3				1					
	4918962	555541				52	2										34
7/18	4919420	553142	15	1	1	54						1				9	
	4919356	553457	1426			12		9									
	4919271	553614	1		1	31		14									
	4918962	555541	1			34											2
8/19	4919420	553142	7		2	11		2									
	4919356	553457	7					151									
8/21	4919271	553614	11	2	1	3		30									
	4918962	555541				42									6		5
TOTAL			1652	31	67	906	2	218	0	0	2	14	0	0	6	9	41
PERCENT			56.0	1.1	2.3	30.7	0.1	7.4			0.1	0.5			0.2	0.3	1.4

Appendix 20. Average fish lengths of each species captured during 2003 inventory of Northeast Creek. The date and GPS coordinate placement of the seines are identified. Abbreviation identification is located in Appendix 1.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	PLPU	NOCR	ARFE	ALAE	FUDI
			cm	Cm	cm	Cm	cm	cm	Cm	cm	Cm	cm	cm	cm	cm	cm			
6/24	4919420	553142	4.1	2.3		2.9		9.1			7.3								
	4919356	553457	5.1	2.1	3.9	3.1		8.9				3.3							
	4919271	553614	5.7	2.3	3.3	4.1		8.9				5.9							
	4918962	555541				3.7	8.1												4
7/18	4919420	553142	4	2.1	4.1	3						3.7						9.4	
	4919356	553457	5.3			2.8		2											
	4919271	553614	5.3		2.8	2.2		6.9											
	4918962	555541	5.8			2.4													6.9
8/19	4919420	553142	3.8		4.4	3.7		6.6											
	4919356	553457	5					4.2											
8/21	4919271	553614	3.2	2.2	3.9	3.1		3.4											
	4918962	555541				2.8										8			3

Appendix 21. Fish species captured during 2002 inventory of Mosquito Cove. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling, visual) used is identified as well as GPS coordinates of location of fishing effort. Fish lengths are reported in Appendix 22. Abbreviation identification is located in Appendix 1. "Saltwater" indicates that the saltwater side of the estuary was sampled from the fyke net.

Date	Time	Gear	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	TAAD	MYSC	MYAE
					#	#	#	#	#	#	#	#	#	#	#	#	#
8/7	13:00	D	4913284	574612	11					28							
		D	4913272	574631	12				1								
		V	4913284	574612	A					A							
8/8	13:00	D	4913402	574488	33					1	31						
		D	4913394	574512							3						
8/9	9:00	V	4913895	574067													
		A	4913895	574067								3				1	
8/9	10:00	MA	4914005	573999													1
		MB	4913937	574036											6		
		MC	4913920	574062					1								
		MD	4913905	574061													
		ME	4913746	574232													
		MF	4913688	574341													
		MG	4913529	574524													
		MH	4913328	574602	57												
		MI	4913284	574612	9												
TOTAL					122	0	0	0	2	29	34	3	0	0	6	1	1
PERCENT					61.6				1.0	14.6	17.2	1.5			3.0	0.5	0.5

Appendix 22. Average fish length for each species captured during 2002 inventory of Mosquito Cove. Date, time and fishing gear (seine, dip net, fyke net, minnow trap, angling, visual) used is identified as well as GPS coordinates of location of fishing effort. Abbreviation identification is located in Appendix 1.

Date	Time	Gear	northing	Easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	SCSC	PHGU	ALPS	TAAD	MYSC	MYAE
					cm	cm	cm	cm	cm	cm	Cm	cm	cm	cm	cm	cm	cm
8/7	13:00	D	4913284	574612	1.6					2.7							
		D	4913272	574631	3.5				5.3								
		V	4913284	574612	NM					NM							
8/8	13:00	D	4913402	574488	3.4					1.3	2						
		D	4913394	574512							2.7						
8/9	9:00	V	4913895	574067													
		A	4913895	574067								32				14.9	
8/9	10:00	MA	4914005	573999													11
		MB	4913937	574036											5.8		
		MC	4913920	574062					21.7								
		MD	4913905	574061													
		ME	4913746	574232													
		MF	4913688	574341													
		MG	4913529	574524													
		MH	4913328	574602	5.9												
		MI	4913284	574612	5.9												

Appendix 23. Fish species captured during 2003 inventory of Mosquito Cove. The date and GPS coordinate placement of the seines are identified. Fish lengths are reported in Appendix 24. Abbreviation identification is located in Appendix 1.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	NOCR	ALAE	FUDI
			#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
6/25	4914030	573967															
	4913721	574372															
	4913825	574088			1					3							
	4913312	574586	1														
7/22	4914030	573967															
	4913721	574372				34								3			
	4913825	574088	3													2	
	4913312	574586	12													1	
8/20	4914030	573967															
	4913825	574088	1														
	4913312	574586	113					11									
TOTAL			130	0	1	34	0	11	0	3	0	0	0	3	0	3	0
PERCENT			70.3		0.5	18.4		5.9		1.6				1.6		1.6	

Appendix 24. Average fish length of each species captured during 2003 inventory of Mosquito Cove. The date and GPS coordinate placement of the seines are identified. Abbreviation identification is located in Appendix 1.

Date	northing	easting	FUHE	GAAC	APQU	PUPU	ANRO	MEME	CYLU	CLHA	ALPS	GAWH	SYFU	AMAM	PLPU	NOCR	ARFE	ALAE	FUDI
			cm	cm	cm	cm	cm	cm	cm	cm	Cm	cm	cm	cm	cm	cm			
6/25	4914030	573967																	
	4913721	574372																	
	4913825	574088			4.1					5.3									
	4913312	574586	4.9																
7/22	4914030	573967																	
	4913721	574372				3								5.5					
	4913825	574088	5.4															8.1	
	4913312	574586	0.9															6.9	
8/20	4914030	573967																	
	4913825	574088	3																
	4913312	574586	3.4					3.3											

Appendix 25. Bird species observed in area during fish inventory of estuaries. Abbreviation identification is located in Appendix 1.

Date	Time	northing	easting	HALE	PAHA	COBR	ANPL	MEAL	ARHE	DRPI	SC	PHAU
Sea Cove												
6/15/02	15:30	4903772	547893	1	1	>1	>1	2	1			
8/20/02	16:30	4903772	547893	2	1		4	2		1	>1	
8/23/02	6:00	4903666	547907				1					
Somes Sound												
9/7/02	10:30	4913074	553474					2	1			
Bass Harbor												
6/28/02	16:30	4901569	552188						1			
Northeast Creek												
7/9/02	19:30	4919312	553504				>1					
7/10/02	18:00	4918577	554592		1							
9/13/02	20:30	4919000	553700				5					
9/13/02	20:30	4918934	554294					2	1			
9/17/02	7:30	4919257	553589				4	1	1			1

Appendix 26. Temperature (C) and salinity (ppt) measurements of the surface (S) and bottom (B) water of the estuaries during the fish inventory in 2003.

Date	northing	easting	ST C	salinity ppt	BT C	salinity ppt
Seal Cove						
6/16	4904025	547825	10.9	1.3	9.4	31.8
	4903758	547907	17.6	2.4	15.4	23.9
	4903594	547850	16	2.3	11	31.3
7/15	4904025	547825	15.6	30.3	14.2	31.4
	4903758	547907	15.7	30.3	14.4	31.4
7/16	4903594	547850	18.1	1.1	15.1	28.1
8/17	4904025	547825	21	28.9	17.8	30.5
	4903758	547907	NM	NM	NM	NM
	4903594	547850	25.8	2.2	20.8	29.7
Somes Sound						
6/19	4913129	553487	15	27.7	13.7	30.4
	4913688	553473	20.9	8.6	19.1	22.1
	4913927	553335	17	2.0	15	25.2
7/17	4913129	553487	17	6.4	16.4	31.4
	4913688	553473	18.8	10.8	19	30.1
	4913927	553335	27	23.7	22	29.8
8/16	4913129	553487	20	30.3	20	30.5
	4913688	553473	26	30.3	22	30.2
	4913927	553335	32	29.0	27	29.8
Bass Harbor						
6/21	4901578	552199	23	12.0	NM	NM
	4902331	551469	18	0.0	NM	NM
6/22	4900074	551927	13	1.7	11	31.3
	4900874	552329	18	18.0	14	28.6
7/16	4901578	552199	20	24.0	20	25.0
	4902331	551469	19.7	1.2	23	13.8
7/21	4900074	551927	17	30.4	16	32.5
	4900874	552329	20	30.3	19	30.5
8/17	4900074	551927	30	29.9	16	30.5
	4900874	552329	22	29.2	28	8.2
	4901578	552199	28	8.2	28	8.2
	4913890	573957	20	0.3	25	3.5
	4902331	551469	19	0.0	17.9	0.5

Appendix 26. cont.

NE Creek						
6/24	4919420	553142	14	29.7	14	30.5
	4919356	553457	19	3.3	16	26.1
	4919271	553614	25	0.5	21	13.1
	4918962	555541	24	0.1	16	0.2
7/18	4919420	553142	18	31.6	18	32.2
	4919356	553457	25	26.5	22	30.5
	4919271	553614	23	17.9	24	27.0
	4918962	555541	19	0.3	27	14.8
8/19	4919420	553142	24	30.1	21	30.5
	4919356	553457	26	30.0	25	30.2
8/21	4919271	553614	26	20.5	27	28.5
	4918962	555541	23	0.3	31	11.3
Mosquito Cove						
6/25	4914030	573967	12	31.0	12	31.0
	4913721	574372	NM	NM	NM	NM
	4913825	574088	15	30.0	13	30.6
	4913312	574586	14	29.2	14	30.3
7/22	4914030	573967	15	31.8	14.6	31.8
	4913721	574372	15	31.3	15	31.3
	4913825	574088	15	31.3	15	31.3
	4913312	574586	16	31.1	16	31.1
8/20	4914030	573967	13	30.9	18	31.0
	4913825	574088	23	30.9	18	31.0
	4913312	574586	25	30.9	22	31.2

Appendix 27. Invertebrate abundance in esturaries for each sampling date and location. CRSE=*Crangon septemspinosa*; CAMA = *Carcinus maenas*; PA = *Pagurus spp.*; LILI = *Littorina littoria*; MY = *Mytilus spp.*; PRFL = *Praunus flexuosus;* ASVU = *Asterias vulgaris;* lngth= average length, expressed in centimeters; NM=not measured; A= abundant. "Saltwater" indicates that the saltwater side of the estuary was sampled from the fyke net.

					CRSE		CAMA		PA		LILI		MY		PRFL		ASVU	
Date	Time	Gear	northing	easting	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth
Seal Cove																		
6/13	15:30	LS	4903758	547907	534	2.6	15	NM										
		D	4903769	547862	91	4.5												
		D	4903780	547869														
6/14	7:00	F	4903750	547916	91	4.5												
6/14	16:00	F	4903750	547916	84	4.7												
		MA	4903808	547857	5	4.6												
		MB	4903774	547862	5	5.2												
		MC	4903780	547869	6	4.3												
		MD	4903759	547867														
		ME	4903760	547874	2	4.7												
		MF	4903762	547881														
		MG	4903766	547888	2	4.7												
		MH	4903709	547867	1	5.3												
		MI	4903735	547899	29	4.9												
6/15	7:00	F	4903750	547916	75	NM												
		F	SALTWATER		57	NM	1	NM										
		MA	4903808	547856	6	4.2												
		MB	4903774	547862	27	4.6												
		MC	4903780	547869	8	4.6												
		MD	4903758	547867														
		ME	4903760	547873	2	5.1												
		MF	4903762	547881	1	5.9												
		MG	4903766	547888	33	4.2												
		MH	4903709	547867	1	4.6	1	NM										
		MI	4903735	547899	5	4.6												

6/15	11:30	MA	4903808	547856	1	NM												
		MB	4903774	547862	2	2.6												
		MC	4903780	547869	3	2.7												
		MD	4903758	547867														
		ME	4903760	547873	1	NM	1	NM										
		MF	4903762	547881			1	NM										
		MG	4903766	547888														
		MH	4903709	547867														
6/15	15:30	F	4903750	547916	58	NM												
			SALTWATER		25	4.5												
		MA	4903808	547856	2	4.3												
		MB	4903774	547862	13	4.6												
		MC	4903780	547869	13	4.5												
		MD	4903758	547867	1	5.4												
		ME	4903760	547873														
		MF	4903762	547881														
		MG	4903766	547888	1	4.6												
		MH	4903709	547867														
		MI	4903735	547899														
		BS	4903783	547865														
		V	4903772	547893														
0.4	16:30	MA	4903808	547856														
		MB	4903774	547862														
		MC	4903780	547869														
		MD	4903758	547867			1	NM										
		ME	4903760	547873														
		MF	4903762	547881														
		MG	4903766	547888														
		MH	4903709	547867														
		MI	4903735	547899	1	3.9												
		V	4903772	547893														

8/21	15:30	F	4903750	547916	1	4.5											
		MA	4903808	547856													
		MB	4903774	547862			1	NM									
		MC	4903780	547869			1	NM									
		MD	4903758	547867			1	NM									
		ME	4903760	547873			1	NM									
		MF	4903762	547881													
		MG	4903766	547888													
8/21	23:00	D	4903840	547848													
8/22	6:30	F	4903750	547916	6	4.3											
		MZ	4903999	547827													
		MA	4903808	547856			1	NM									
		MB	4903774	547862	1	8.9											
		MC	4903780	547869			1	NM									
		MD	4903758	547867			2	NM									
		ME	4903760	547873			117	NM									
		MF	4903762	547881													
		MG	4903766	547888													
		MH	4903709	547867													
		MI	4903735	547899	4	4.2	9	NM									
8/22	14:00	MA	4903808	547856													
		MB	4903774	547862			2	NM									
		MC	4903780	547869													
		MD	4903758	547867													
		ME	4903760	547873			8	NM									
		MF	4903762	547881			2	NM									
		MG	4903766	547888			1	NM									
		MH	4903709	547867	2	4.7	3	NM									
		D	4903879	547841													
		D	4903766	547888													
		V	4903893	547849													

8/23	6:00	F	4903750	547916	9	4.3	59	NM										
		MZ	4903999	547827														
		MA	4903808	547856														
		MB	4903774	547862														
		MC	4903780	547869			4	NM										
		MD	4903758	547867			1	NM										
		ME	4903760	547873	1	3.9	6	NM										
		MF	4903762	547881														
		MG	4903766	547888			2	NM										
		MH	4903709	547867														
		MI	4903735	547899	1	3.6	16	NM										
		D	4903925	547847														
		D	4903888	547840														
8/23	12:00	MA	4903808	547856														
		MB	4903774	547862														
		MC	4903780	547869	2	4.1	1	NM										
		MD	4903758	547867														
		ME	4903760	547873			7	NM										
		MF	4903762	547881														
		MG	4903766	547888			4	NM										
		MH	4903709	547867			5	NM										
		MI	4903735	547899														
		AG	4903419	547505														

					CRSE		CAMA		PA		LILI		MY		PRFL		ASVU	
Date	Time	Gear	northing	easting	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth
Somes Sound																		
7/1	15:30	D	4913229	553410	3	3.3												
		D	4913206	553462														
		D	4913129	553487	25	4.2												
		D	4913927	553335														
		V	4913088	553471	A		A		A		A		A					
7/1	13:40	MA	4913074	553474			2	NM										
		MB	4913099	553474														
		MC	4913097	553456	1	4.3	1	NM										
		MD	4913139	553475			1	NM										
		ME	4913130	553461	12	4.4												
		MF	4913132	553441														
		MG	4913128	553425			1	NM										
		MH	4913229	553427			2	NM	1	NM								
		MI	4913403	553445			1	NM										
7/3	13:00	F	4913791	553638			6	NM										
		F	SALTWATER				3	NM										
		V	SALT MARSH															
		D	4913727	553472														
7/3	16:00	MA	4913074	553474														
		MB	4913099	553474			1	NM										
		MC	4913097	553456														
		MD	4913139	553475														
		ME	4913130	553461														
		MF	4913132	553441	3	4.1												
		MJ	4913676	553541			3	NM										
		MK	4913765	553374			8	NM										
7/4	13:00	F	4913791	553638			4	NM										
			SALTWATER		1	4.3	2	NM										
		V	4913762	553641														

7/4	14:30	MA	4913074	553474			5	NM										
		MB	4913097	553474			1	NM										
		MC	4913097	553456			2	NM	1	NM								
		MD	4913139	553475			2	NM										
		MF	4913132	553441	1	4.7												
		MG	4913128	553425			13	NM										
		MH	4913229	553427														
		MI	4913403	553445	4	4.4	3	NM										
		MJ	4913676	553541														
		MK	4913676	553374														
9/6	15:30	MC	4913765	553374														
9/7	10:30	MA	4913796	553665														
		MB	4913676	553541														
		MC	4913765	553374	1	4.5												
		MD	4913403	553445			5	NM										
		ME	4913128	553425	1	2.1	5	NM										
		MF	4913135	553452			1	NM										
		MG	4913139	553475			8	NM										
		MH	4913074	553474			8	NM										
		LS	4913129	553487														
9/7	10:30	MA	4913796	553665														
		MB	4913676	553541														
		MC	4913765	553374			2	NM										
		MD	4913403	553445			6	NM										
		ME	4913128	553425														
		MF	4913135	553452														
		MG	4913139	553475														
		MH	4913074	553474			2	NM										

9/8	12:00	MA	4913796	553665														
		MB	4913676	553541														
		MC	4913765	553374			5	NM										
		MD	4913403	553445			5	NM										
		ME	4913128	553425														
		MF	4913135	553452			4	NM										
		MG	4913139	553475	1	4.2	4	NM									1	NM
		MH	4913074	553474			5	NM										
		LS	4913129	553487														
9/8	18:00	MA	4913796	553665	4	4.4												
		MB	4913676	553541	1	5.1												
		MC	4913765	553374			2	NM										
		MD	4913403	553445			1	NM										
		ME	4913128	553425														
		MF	4913135	553452			2	NM										
		MG	4913139	553475														

					CRSE		CAMA		PA		LILI		MY		PRFL		ASVU	
Date	Time	Gear	northing	easting	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth
Bass Harbor																		
6/24	6:15	MA	4900155	551945			3	NM										
		MB	4900187	551955														
		MC	4900185	551963														
		MD	4900175	552004	1	4.5												
		ME	4900217	552040	5	4.3									1	4.3		
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110														
		MI	4900671	552303														
		F	4900236	551972	1	4.5												
6/24	19:10	MA	4900155	551945														
		MB	4900187	551955														
		MC	4900185	551963			1	NM										
		MD	4900175	552004				1	NM									
		ME	4900217	552040														
		MF	4900227	552024														
		MG	4900232	552001														
		MH	4900408	552110			1	NM							3	4.6		
		MI	4900671	552303	1	NM												
		F	4900267	552011	22	4.8	23	NM										
			SALTWATER		11	4.7	13	NM							A			
6/25	9:50	MA	4900155	551945			1	NM										
		MB	4900187	551955														
		MC	4900185	551963			1	NM										
		MD	4900175	552004			1	NM										
		ME	4900217	552040	3	4												
		MF	4900227	552024														
		MG	4900232	552001			2	NM										
		MH	4900408	552110														
		MI	4900671	552303	1	NM												

6/25	17:50	MA	4900155	551945														
		MB	4900187	551955			2	NM										
		MC	4900185	551963														
		MD	4900175	552004														
		ME	4900217	552040			2	4.3										
		MF	4900227	552024	2	4.3												
		MG	4900232	552001			3	NM										
		MH	4900408	552110														
		MI	4900671	552303														
		D	4900175	552004	A										A			
		D	4900267	552011														
		F	4900267	552011	4	4.1	2	NM										
			SALTWATER		4	4.8	5	NM										
6/26	18:30	V																
6/28	13:35	D	4902331	551469														
		D	4902091	551748														
6/28	16:30	MJ	4901572	552164														
		MK	4901569	552188														
		ML	4901544	552220														
		MM	4901528	552236														
		V	4901569	552188														
6/28	17:50	MK	4901569	552188														
8/23	13:00	D	4900175	552004														
		MA	4900126	551907			4	NM										
		MB	4900155	551945														
		MC	4900175	552004	2	5												
		MD	4900187	551955	3	4.5												
		ME	4900185	551963	1	4.5	2	NM										
		MF	4900227	552024	8	4.5												
		MH	4900671	552303			2	NM										
		MI	4900238	552578														

8/24	9:30	MA	4900126	551907			1	NM										
		MB	4900155	551945			1	NM										
		MC	4900175	552004	1	4.8	4	NM										
		MD	4900187	551955			3	NM										
		ME	4900185	551963			1	NM										
		MF	4900227	552024	1	4.2												
		MG	4900408	552110			3	NM										
		MH	4900671	552303			3	NM										
		MI	4900238	552578	1	5.4												
8/24	15:30	MA	4900126	551907	1	3.8	1	NM										
		MB	4900155	551945			1	NM										
		MC	4900175	552004			4	NM										
		MD	4900187	551955			1	NM										
		ME	4900185	551963			1	NM										
		MF	4900227	552024	1	4.2	2	NM										
		MG	4900408	552110			1	NM										
		MH	4900671	552303														
		MI	4900238	552578														
		D	4900187	551955														
		D	4900238	552578														
8/25	10:30	MA	4900126	551907														
		MB	4900155	551945														
		MC	4900175	552004			4	NM										
		MD	4900187	551955														
		ME	4900185	551963			5	NM										
		MF	4900227	552024	1	3.8												
		MG	4900408	552110	3	4.1	1	NM										
		MH	4900671	552303	9	4.2												
		F	4900267	552011	3	4.1												

8/25	16:00	MA	4900126	4900126			5	NM										
		MB	4900155	551945														
		MC	4900175	552004			2	NM										
		MD	4900187	551955														
		ME	4900185	551963														
		MF	4900227	552024														
		MG	4900408	552110	1	4.4												
		MH	4900671	552303														
		MI	4900238	552578														
8/30	12:30	D	4900671	552303														
8/30	18:30	MJ	4901572	552164														
		MK	4901569	552188														
		ML	4901544	552220														
		MM	4901528	552236														
		MN	4901992	551859														
		MP	4902213	551585														
		MQ	4902331	551469														
8/31	9:40	MJ	4901572	552164														
		MK	4901569	552188														
		ML	4901544	552220														
		MM	4901528	552236														
		MN	4901992	551859														
		MO	4902091	551748														
		MP	4902213	551585														
		MQ	4902331	551469														
		LS	4901991	551802														
9/1	19:00	MJ	4901572	552164														
		MK	4901569	552188														
		ML	4901544	552220														
		MM	4901528	552236														
		MN	4901992	551859														
		MP	4902213	551585														
		MQ	4902331	551469														

					CRSE		CAMA		PA		LILI		MY		CORIX		ANIS LAR	
Date	Time	Gear	northing	easting	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth
NE Creek																		
7/8	20:00	D	4919296	553569														
7/9	19:30	F	4919320	553514	1	NM	5	NM										
			SALTWATER				11	NM										
		MA	4919389	553435														
		MB	4919305	553474														
		MC	4919309	553488														
		MD	4919312	553504														
		ME	4919289	553563														
		MF	4919296	553569														
		MG	4919257	553589														
		MH	4918934	554294														
		MI	4918557	554681														
7/10	18:00	MA	4919389	553435														
		MB	4919305	553474														
		MC	4919309	553488														
		MD	4919312	553504														
		ME	4919289	553563														
		MF	4919296	553569														
		MG	4919257	553589														
		MH	4918934	554294														
		MI	4918557	554681														
		D	4919271	553614														
		D	4918986	555586														
7/10	19:00	F	4919320	553514			3	NM										
			SALTWATER				6	NM										

9/14	17:30	MA	4919389	553435														
		MB	4919305	553474														
		MC	4919309	553488														
		MD	4919312	553504														
		MF	4919289	553563														
		MG	4919257	553589														
		MH	4918934	554294														
		MI	4918557	554681														
		D	4919353	553488														
		D	4919309	553488														
9/15	18:00	MA	4919389	553435														
		MB	4919305	553474														
		MC	4919309	553488	1	5.1												
		MD	4919312	553504														
		MF	4919296	553569														
		MG	4919257	553589														
		MH	4918934	554294														
		MI	4918557	554681														
9/16	16:00	MA	4919305	553474														
		MB	4919305	553474														
		MC	4919309	553488														
		MD	4919312	553504														
		MF	4919296	553569														
		MG	4919257	553589														
		MH	4918934	554294														
		MI	4918557	554681														
		SS	4919271	553614	1	5.5												
		D	4918986	555586											A	NM	A	NM
9/16	19:30	MB	4919305	553474														
		MC	4919309	553488														
		MF	4919296	553569														
9/17	7:30	MG	4919257	553589														
		MH	4918934	554294														
		MI	4918557	554681														

					CRSE		CAMA		PA		LILI		MY		PRFL		ASVU	
Date	Time	Gear	northing	easting	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth	#	lngth
Mosquito Cove																		
8/7	13:00	D	4913284	574612														
		D	4913272	574631														
		V	4913284	574612														
8/8	13:00	D	4913402	574488														
		D	4913394	574512														
8/9	9:00	V	4913895	574067														
		A	4913895	574067														
8/9	10:00	MA	4914005	573999														
		MB	4913937	574036														
		MC	4913920	574062														
		MD	4913905	574061														
		ME	4913746	574232														
		MF	4913688	574341														
		MG	4913529	574524														
		MH	4913328	574602														
		MI	4913284	574612														